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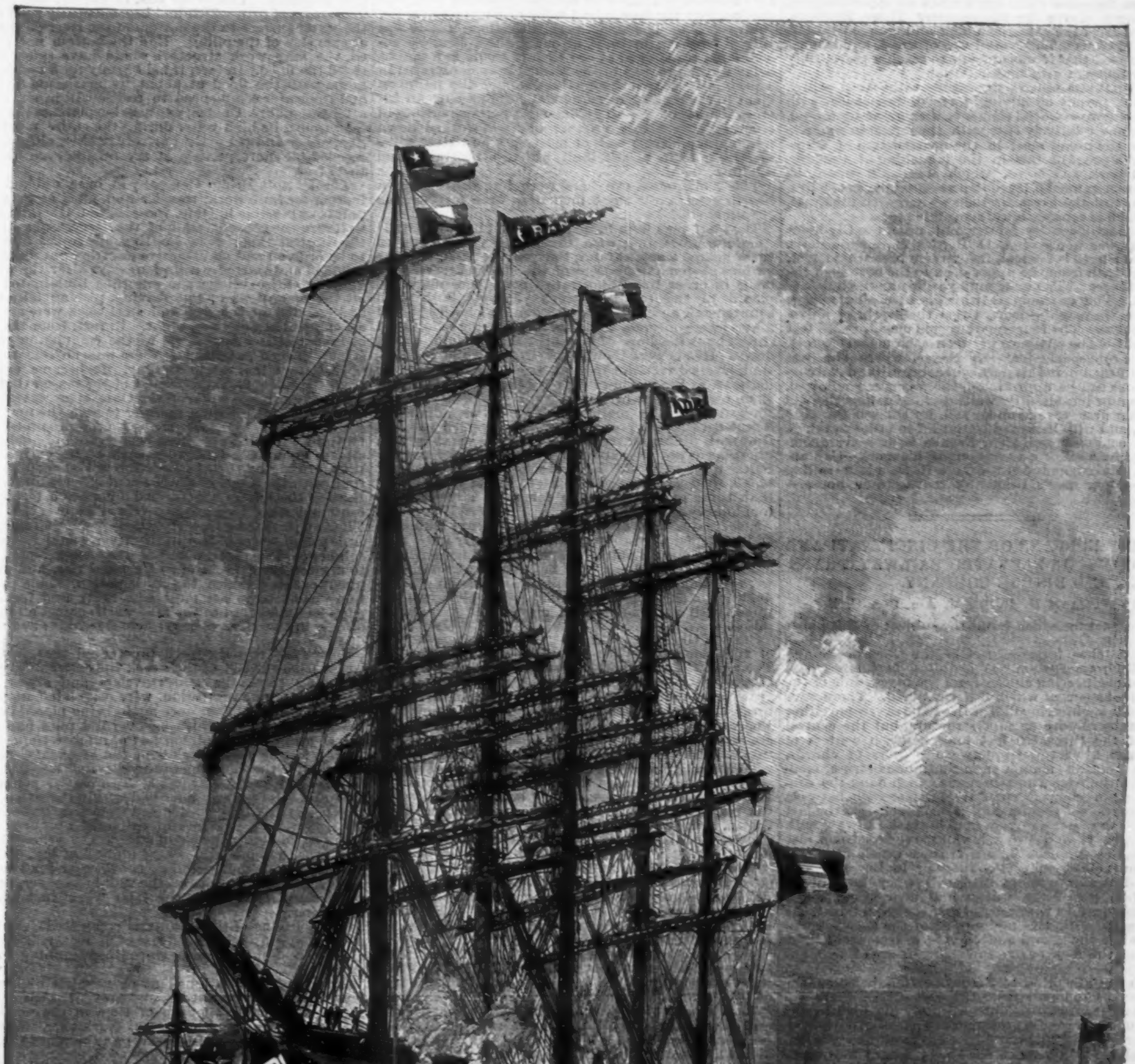


LA FRANCE—THE LARGEST SAILING VESSEL AFLOAT—6,160 TONS.

THE FIVE-MASTED SHIP LA FRANCE—THE LARGEST SAILING VESSEL AFLOAT.

A QUARTER of a century ago, at the epoch in which the opening of the Suez Canal foreshadowed important modifications in the conditions of carriage by sea, there was a general agreement in the prediction that sailing vessels were to disappear and give way, upon all lines, to steamships. The reign of vessels of small tonnage was, in fact, finished, and at this time it was impossible to think of constructing wooden sailing vessels having a sufficient capacity (seeing the competition of large steamers) to permit of making remunerative voyages of long distances. But people were deceived. It was supposed at this epoch that the science of building sailing vessels would remain stationary, just as if all sciences ought not to make progress together. The sequel has shown the error of such a supposition, for a few years ago we had an opportunity of admiring at Havre the three-master Three Brothers, which carried the American flag and gauged no less than 2,936 tons. This vessel was of wood, and it must be confessed that it was difficult to reach a perceptibly greater tonnage with that material.

But what was almost impossible with wood, which does not permit of allying force of resistance with lightness (two essential elements with great tonnages), has become relatively easy with the immense progress made in the use of steel in the construction of ships. We had a proof of this in the launching of the four-masted bark the Nord, which was built upon the Clyde, and gauged 5,150 tons, and especially in the five-masted bark the France, which we herewith illustrate, and which is capable of carrying 6,160 tons.

This magnificent vessel was built upon the Clyde for the shipping house of A. D. Bordes & Son, of Paris. Its total length is 376 feet, its extreme breadth 50 feet, and its depth from the upper deck to the bottom of the hull is 34 feet. The masts and yards, like the hull, are of steel. The mizzenmast, which is in a single piece, is 141 feet in height—nearly twice the height of a five-story house. The four square-rigged masts are 195 feet in height. The distance between each mast is 69 feet.

The France has just left Havre, where she was Frenchified; and in this port, where beautiful naval constructions can be appreciated, she was much admired. We are now impatiently waiting to see how she will effect her first voyage under sail, for she was towed to Havre, and will be towed to Cardiff in order to take a load of coal on board. The France is, moreover, commanded by a sailor who has made his mark—Captain Voisin, who commanded the Cape Horn, a large sailing vessel of four masts belonging to the same house.—*L'Illustration.*

THE RIVER SPANS OF THE CINCINNATI AND COVINGTON ELEVATED RAILWAY, TRANSFER AND BRIDGE COMPANY.

By WILLIAM H. BURR, M. Am. Soc. C. E.

THE structure which forms the subject of this paper crosses the Ohio River at Cincinnati, Ohio, and with its approaches forms a part of the Chesapeake and Ohio Railroad system. It acquires its interest as a piece of engineering chiefly from the magnitude of the individual spans of which it is composed. There were no special engineering difficulties to be overcome either in the substructure or superstructure, but the central span of the three, 550 feet long between centers of piers, and 84 feet deep between centers of chords, is the greatest simple non-continuous truss span yet constructed. The two spans which flank the center or main channel span are 490 feet each between pier centers, with center depths of 75 feet; and the fact that all the spans carry a double track railway, with two roadways and two sidewalks, renders them also the heaviest non-continuous trusses which have yet been built either in this country or in Europe. The detail drawings accompanying this paper show all the main features of the trusses and floor systems and their connections which are of any special interest. As they indicate, all the main parts of the trusses are of steel, while the lateral and transverse systems of bracing and the floor beams and stringers are of wrought iron.

With the exception of the connection between the floor beams and posts, and the web system, there will be found few features not ordinarily included in the best American practice for heavy spans. All connections are central, and so designed as to eliminate essentially all secondary stresses. The system of web members used, and which has been developed by the Phœnix Bridge Company for its long spans, is seen to be single, and it is of interest in passing to note that if a single system of bracing may be used for trusses of the dimensions and weight of these under consideration, there would seem to be no case where it may not be advantageously employed. There is thus avoided all the ambiguity and secondary stresses which are inevitable to a greater or less degree when any multiple system of web members is used.

The boring of individual truss members was done with such lengths as would eliminate all secondary stresses whatever at a condition of loading intermediate between no moving load and a full moving load. As the latter condition of loading will very rarely occur, these normal lengths will reduce the secondary stresses to an absolute minimum; in fact, will reduce them to such small magnitude as to leave them with no importance whatever. The connection between the floor beams and posts, which is made by means of close fitting turned bolts in holes drilled with those members assembled, is of such a character as to secure all the advantages of a rigid connection, and at the same time eliminate all tension upon the connecting bolts, leaving them to transfer shear only; at the same time the weights of both railway and highway floor systems are transferred centrally, so as to bring an equal distribution of weights upon all of the web members intersecting at any lower chord panel point. Under the requirements of the specifications all rivet holes in the plates and angles forming the upper chords and end posts, and nearly all intermediate posts, were made with multiple drills of six drills in a gang. The only exceptions to this statement were some light plates and angles in a few of the intermediate posts, which were punched and reamed.

Much difficulty was experienced in obtaining metal for the heavy plate links at the upper ends of the end posts which would fill the requirements of the specifications, or sufficiently near thereto. A number of steel plate makers felt confident of being able to produce such thick and heavy plates as would meet the requirements of this case, but repeated trials were failures.

The metal would be very low in elastic limit as well as in ultimate, and develop porous places in the interior of the mass. The whole difficulty lay in the small amount of work which was put upon the metal between the ingot and finished plate. Messrs. Graff, Bennett & Co. finally produced a number of plates of open hearth steel which met the requirements of the specifications.

Their financial difficulties coming on at this time, however, prevented their completion of more than a few only of the plates required. The remaining plates for these heavy links were made of Bessemer steel and produced at the Homestead mills of Messrs. Carnegie, Phipps & Co. The experience with these plates was very interesting in itself, although the difficulties encountered threatened at one time to result in a serious delay to the progress of the work. It demonstrated in a peculiarly clear and effective manner the improvement in the quality of the metal produced by an increased amount of work. The most porous portions of several plates were a number of times worked down under a hammer to bars of most excellent steel, alike in respect to its elastic limit, ultimate resistance and ductility.

The 7 inch steel eye bars were forged from open hearth steel, while the 8 inch bars were forged from Bessemer steel.

The steel pins were forged from open hearth metal.

Before proceeding with the actual shop work on these spans, many careful tests on the effect of the various shop manipulations of the steel material were made in order that the greatest confidence might be placed in the resulting work. Rivets both with countersunk and full heads on one and both sides of plates were driven, and the hammering continued throughout the stage of blue heat as the metal cooled down. Heads were then knocked off, or the countersunk rivets driven out in such a way as to give their material as much abuse as possible. The results of these tests were in every way highly satisfactory and showed that the material selected was admirably adapted to its purpose. They also revealed the fact that with proper material in steel rivets, that is, with phosphorus not over about five hundredths of one per cent., and with an ultimate resistance of about 60,000, they can be used so as to stand more abuse than those of iron and give far more strength and toughness.

Steel plates were also sledged with heavy hammers and stretched at various points irregularly until they were badly curved out of shape and left curved with hammer marks. After this maltreatment specimens were cut out and tested in tension and bending. The ductility in such cases was found to be only a little injured, with an ultimate and elastic limit somewhat raised.

Some of these tests were reported in the *Transactions* of this Society for October, 1887, vol. xvii., p. 185. The results of these special tests and the general result of the whole work demonstrated the fact that the growing confidence which has been placed in structural steel is not misplaced, but most firmly founded. The various tables of results appended to this paper are extracted from the various tests which were made to establish the character of the material in the general progress of the work. They are true representations in all cases of the average results obtained. The entire record of tests has not been incorporated in this paper for the reason that a very large number are shown, and the whole would have added unwieldly bulk to it without conveying any additional information.

The specifications under which this work was executed were drawn up and proposed by the Phœnix Bridge Company, by whom the entire work of these spans was designed, constructed and erected and accepted by the Covington and Cincinnati Elevated Railway, Transfer and Bridge Company.

The actual shop work of the construction of these spans was begun in March, 1888, and the last of the three spans was coupled and traffic passed on the 25th of December of the same year.

The weight of the iron and steel in two 490 foot and one 550 foot spans is almost exactly 10,000,000 pounds. The length of the Covington approach is about 1,533 feet, while that of the Cincinnati approach, including the structure carrying the many diverging tracks to the freight depot, is nearly 2,300 feet, making a total length of structure carrying a double track railway, double roadway and sidewalks of almost exactly one mile. The total weight of metal in this entire structure is 20,360,000 pounds.

The work of erection of these spans under ordinary circumstances involved no special difficulties, but the abnormal character of the season demonstrated with great intensity the full dangers which may beset any work carried on in the Ohio river. In June, 1888, as soon as the stage of the water would permit, false work was begun at the Covington end of the south 490 foot span.

In the early part of August this span was safely coupled, after a most dangerous flood in the river during the latter part of July. This flood caused a rise in the river of about 25 feet. Large quantities of drift were brought down by the current and lodged against the false work then carrying the large traveler and about two thirds of the trusses and railway floor. The pressure of this mass was so great that it pushed the false work about one foot down stream, but did no other damage. Incessant rains made it impossible to commence putting the iron of the 550 foot span on the false work until about the middle of August. Shortly after that time the river experienced another flood rise of 27 feet, with enormous quantities of drift. These conditions prevented much progress in the work, but on August 26 about 700,000 pounds of iron and steel railway floor and eye bars were placed on the false work, which at that time was not quite completed for the 550 foot span. For several days previous to August 26, it became evident that the high water was becoming exceedingly dangerous, and the entire erection force was occupied in attempts to protect the work that had already been done and remove so far as possible the drift which was continually coming down the river.

But on that date (August 26), with some 36 feet of water in the river, the drift formed a continuous mass for over 500 feet up-stream from the bridge, and in spite of expensive temporary protection it swept the false work, the large traveler and nearly 700,000 pounds of iron and steel work down the river in an absolutely complete wreck. Masses of this wreckage were stranded down the river from the bridge site for fully 50 miles, and two steel eye bars were picked up 45 miles from the bridge. Subsequent careful examinations of the river bottom showed that the false work piling failed by a very little only in holding its own safely against the flood and drift. The bottom was found to be scoured out for a considerable portion of the span to an increased depth of 10 to 12 feet, thus removing from the false work piles the support which they required. This scour was, of course, due to the large mass of drift which had become nearly solid from the water surface to the bottom of the river on the up-stream side of the piling. Had the bottom not scoured, the false work structure would have safely withstood the flood. In fact, it held firmly for a number of hours with the flood at about its maximum height, and the water commenced to recede within six hours after the failure. Contrary to usual experience the river maintained its high water during the entire month of September and the early part of October, although it receded for short periods, at several intervals, from 5 to 17 feet.

The Phœnix Bridge Company at once ordered new lumber for false work, traveler and piles at as many points as possible in Ohio, Indiana, and Georgia, so as to insure the concentration of the largest quantity in the shortest time. New hoisting apparatus also had to be ordered and an extensive electric light plant was founded and started within four days after the wreck, and the entire bridge site was thus illuminated and all the operations of pile driving, placing false work and erection of the iron and steel work were actively continued both day and night. In fact, from the day of the wreck, on August 26, to the completion of the structure on December 25, there was no cessation of operations either night or day. It became evident from the phenomenal character of the season that the usual autumn low water in the Ohio river was not to be experienced. Hence, in order to give the new false work of the 550 foot span thorough protection, two lines of heavy piling were run obliquely up-stream about 600 feet from each of its extremities, thus forming by their intersection a V shaped protection, with the angle of the V about 550 feet up stream. Each of these lines was formed by piles 5 feet apart centers, backed by a group of six piles every 40 feet. The two lines were then sheathed by 4 by 6 scantling. A depth of water 45 feet in the river would have just submerged this protection, but it was considered safe to neglect the expectation of such a rise, and subsequent events justified the anticipation. This protection was found to act most admirably and formed a complete safeguard to the false work against a number of rises in the river with very considerable amounts of drift.

So actively was the work prosecuted that just five weeks from the day of the wreck the entire false work, including piles, the two travelers and about 1,200 lineal feet of pile protection, were completed in place, the iron and steel floor once again being placed on the false work. During this time over 950 piles had been driven and nearly a million feet of lumber framed and placed in the false work and the two travelers, the traveler for the handling of the iron and steel being as large as any ever constructed. The 700,000 pounds of iron and steel railway floor had within the same time also been entirely reconstructed from new material at the Phœnixville shops and delivered at Cincinnati. The erection of the iron and steel work of the 550 foot span was then pushed forward night and day, and was entirely completed, including the floor and all lateral and transverse bracing, on the 28th of October, and it was swung clear from the false work immediately thereafter.

The coupling of this span was completed just after a heavy storm with a flood rise of 27 feet, making the third period of high water since the beginning of the work.

This flood rise continued at or near its high water mark for some three weeks, and prevented the driving of any piles for that length of time in the north 490 foot span. During the last of November, however, the water commenced to recede, and the remaining pile driving and false work were soon completed. On December 9, the first iron work for the railway floor was run out on the false work of the north 490 foot span at the Cincinnati end of the structure, and the erection of the remaining iron and steel work was carried on continuously day and night until the last coupling was effected, as stated, on December 25. The placing and erection of all the iron and steel work of this span, including railway floors and all lateral and transverse bracing, was completed in sixteen days, on the last of which the first regular railway traffic passed over the bridge, from which time schedule trains were regularly run.

SUBSTRUCTURE.*

The shore piers of the two 490 ft. spans rest on piles capped transversely of pier with 12 × 12 in. white oak timbers, which in turn carry longitudinally of pier nine lines of the same 12 × 12 in. timbers. These latter carry a solid 12 in. white oak floor or platform about 72 × 36 ft., on which the masonry is placed. The piles are placed 4 ft. apart, centers in both directions. They are white oak sticks driven to refusal 30 to 42 ft. in the clay and gravel of the banks. There are five bottom courses of masonry, each 27 in. thick and each stepped off 12 in. The masonry of the main body of the pier surmounts these bottom courses with the batter and dimensions shown in the cut.

The 24 in. subcoping courses on all the piers are of Kentucky freestone; while all the 24 in. coping courses are oolitic limestone from Salem, Indiana. This latter is a very compact stone and offers a compressive resistance of about 12,000 pounds per square inch; its ratio

* The writer is chiefly indebted to Mr. Epes Randolph, Chief Engineer of the Covington and Cincinnati Elevated Railway, Transfer and Bridge Company, for the ample notes on which the following account of the substructure work (frequently in the words of Mr. Randolph) is based, although Mr. Charles Sooysmith, M. Am. Soc. C. E., has also given him valuable assistance in several particulars.

of absorption does not exceed 2 per cent. of its weight. The belting courses are of a very superior sandstone from the interior of Kentucky, known as Kentucky freestone. It possesses a compressive resistance of about 15,000 pounds per square inch and a ratio of absorption of 3 per cent. The Kentucky shore pier was built of this freestone throughout, while the Ohio shore pier is entirely built of Ohio river freestone. The two river piers are faced with Greensburg limestone, and both are backed with Ohio river freestone from top of caisson to belting course. Above the latter the same backing was used in one river pier and the Kentucky freestone in the other.

The two river piers, one at each end of the 550 foot span, rest on pneumatic caissons 81 ft. 3 in. × 34 ft. 10 in. in plan at cutting edges. The batter of the sides of the caissons is 1 in 15. The walls of the working chamber for a distance of 6 ft. below the roof are 4 ft. thick and composed of three shells of 12 × 12 in. sticks with four of 3 in. sheathing, arranged alternately. The outer shell of 12 in. sticks is carried down 2 ft. below the interior and 1 ft. below the center one; the former carries at its lower extremity a 6 × 9 in. piece of oak chamfered to form the cutting edge. The distance from base of cutting edge or shoe to the roof of the caisson is 8 ft. 9 in. The outside 3 in. sheathing is laid on vertically, and well calked. The inside shell of 3 in. sheathing is also laid on vertically, but the two intermediate shells of the same material are laid diagonally, thus binding each entire wall together in one solid unit. The roof of the working chamber is also covered with 3 in. pine sheathing, and the walls of the working chambers are braced longitudinally to the caisson by two pieces of 12 × 12 inch oak sticks running the entire length and tied securely to the end walls. These longitudinal sticks are held at the proper distance from the roof of the caisson by 12 × 12 in. oak sticks and 1 in. wrought iron rods. The transverse bracing of the walls of the working chamber are held rigidly in place by five 14 × 14 in. oak sticks and 2 in. round wrought iron rods running through the walls to the outside sheathing. The roof of the caisson is formed by seven solid transverse and longitudinal layers of 12 × 12 in. pine sticks.

Above the caisson is constructed the crib work, or grillage, formed of alternate series of four longitudinal and eight transverse 12 × 12 inch pine sticks, with interstices forming by far the larger part of the mass filled with the best concrete. This crib work consists of thirty-five layers in the Ohio caisson and thirty-four layers in the Kentucky one, above which comes the masonry of the pier proper. As the building of the crib progressed, the work of concreting was completed after about every three courses of the timber work were finished. The top of the crib work is about 30 × 76 ft., and the distance from the top of the crib work to the cutting edge is 52 ft. 5 in. for the Ohio and 51 ft. 3 in. for the Kentucky caisson.

The Ohio caisson and crib contains about 527,000 ft. B. M. of timber, and the Kentucky caisson and crib about 514,000 ft. The timber in the caisson and cribs was in the main drift bolted, although some parts of the working chamber were joint bolted, while the 3 in. plank was spiked.

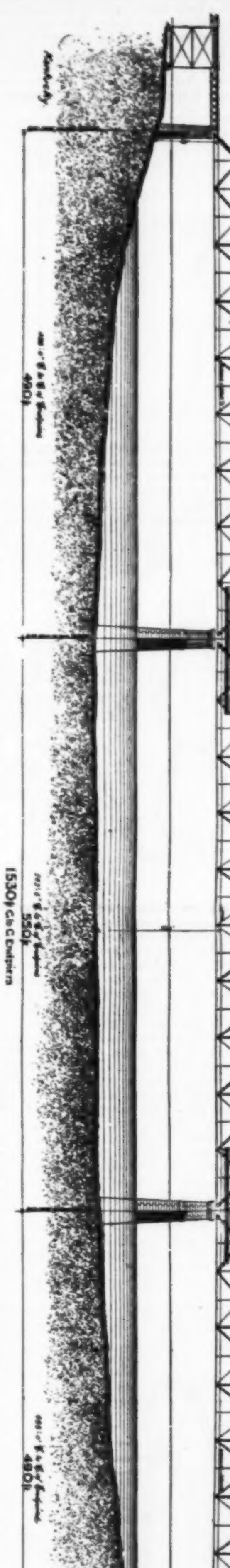
The composition of the concrete used in the crib work was as follows: One part Louisville cement, one part clean sand, and three parts stone broken to pass through a 3 in. ring, all well mixed, with just sufficient water in the sand and cement to give a thick paste. A No. 3 Gates crusher, with a fifteen horse power engine, was used to crush the stone. The capacity of the crusher was about 80 cubic yards per day of ten hours, and the force used in this part of the work consisted of twelve men, one engineer, three men and helper, three men and chute, five men delivering stone to the crusher barge. The chute at which the three men were employed was the channel along which the broken stone was delivered from the crusher to the barge, on which it was carried to the pier in process of construction. The concrete mixer consisted of a Sooysmith proportion meter, screw conveyor and mixer, worked by a six horse power boiler. The usual total force employed in and about the mixer was about twenty-five men, while the concrete force in the crib usually consisted of about twelve men.

The Ohio caisson was launched June 2, 1887, and was kept afloat by a false bottom, which had been placed temporarily just below the oak stiffening timbers, which braced the walls of the working chamber; it was made of 3 in. plank. Immediately after the caisson was launched an air compressor barge was lashed to it, connections made and air used to aid the false bottom to float the caisson. When launched, June 2, the caisson working chamber had only one course of the deck laid above it. From June 2 until June 20 the time was spent in completing the roof or deck of the caisson, after which it was floated into position behind a row of protection or guide piles V shaped, with the angle up stream. The Ohio caisson was settled to river bottom June 20, and rested on a level surface 7 ft. below low water, and the false bottom was entirely removed July 1 by sawing into small pieces and shoving the portions under the cutting edge.

The pneumatic machinery and electric light plant were located on two barges alongside of the caisson and crib. The larger barge, 26 × 96 ft., carried two Ingersol duplex air compressors, two duplex Worthington pumps, 10 × 18, and three boilers. The other barge carried one 10¼ × 18 duplex Worthington pump, one 16 × 24, and one 18 × 30 Ingersol straight line compressor, one Knowles pump and three boilers, and one dynamo, with four arc lights of 1,200 candle power each. Both barges contained machine shop requisites for such work as was found necessary to be done for the repair and maintenance of the entire plant. The air lock was located in the 4 ft. cylinder of a ⅜ in. boiler iron running from the top of the working chamber through the deck and crib work about 18 or 20 ft. above the top of the latter. As the caisson was sunk the cylinder was carried up section by section and masonry built around it.

The inside of the cylinder carried a ladder 15 in. wide with ¾ in. round rungs 16 in. apart. The upper and lower doors or valves of the air lock both swung downward. When a section was added to the cylinder which carried the air lock, the upper door was generally made a lower. In this manner the air lock was gradually carried up as the height of masonry increased. Each door or valve was 20 × 27 in., built of ½ in. wrought plate, to which was riveted

GENERAL ELEVATION OF THE RIVER SPANS OF THE C. C. ELEVATED RAILWAY, TRANSFER, AND BRIDGE CO.



a 1½ × ⅜ in. gasket ring and a 1½ in. rubber gasket, making when closed a tight fit. These doors were raised and lowered by block and tackle.

As the caisson descended and air pressure increased, the time required for the equalization of pressure in the air lock varied from one-half to three minutes, according to the pressure and to the ability of the parties descending to sustain the corresponding changes of pressure. A concrete shaft, 1 ft. 6 in. diameter, of ¼ in. boiler iron, with a door at top and bottom, was located near the middle of the caisson.

The equalizing in this shaft was done from above by means of a 4 in. pipe connection with the working chamber to give compressed air when the concrete was passed downward. It was only used after the caisson was in place for the purpose of supplying concrete to fill the working chamber. Both the air and concrete shafts and also the 4 in. pipes were bolted to the deck course forming the roof of the working chamber. Four-inch pipes were used to discharge gravel and sand from the working chamber. Small piles of gravel and sand would be gathered at the lower openings of the pipes, which projected 6 or 7 ft. into the chamber, after which a valve in the pipe would be opened and the material forced up into the pipe and into the river by the compressed air.

This method was pursued nearly the whole time and removed most of the material. The larger bowlders, rocks, etc., however, were hoisted through the excavating shaft located near the concrete shaft. It was carried up through the deck and crib work about 3 ft. square with its lower end terminating in cylinders about 4 ft. long and 2 ft. 8 in. in diameter, with two doors 1 ft. and 1 ft. 6 in. on opposite sides. This cylinder was bolted to the top of the working chamber and was entirely within it. The bottom was concave, with a small hole 3 × 4 in. just above it. The material was raised in a bucket fitting closely inside this cylinder by means of a derrick on the boat alongside the caisson. There were two openings corresponding to the doors of the cylinder on the upper part of the bucket into which the bowlders, etc., were thrown, after the air in the bucket had been equalized and the doors in the cylinder opened. The bucket was guided through the shaft by two beams projecting over its top, fitting into grooves in the sides of the shaft.

For a short time at the beginning of the work this excavating shaft was not used, and the bowlders were carried down with the caisson, except a small quantity which was locked up through the air shaft in sacks. A sand pump attached to the Worthington pump above and to the ejector below, terminating in a 4 in. rubber hose and strainer, was in frequent use to remove sand, etc., the materials having been stirred up with a jet attached to the ejector just above it. Men worked in eight hour shifts day and night until work was finished. Valves were attached to the lower end of the 4 in. pipes leading from the compressors to the air chamber with automatic closure, in order to give the men ample time to get out if accidents should happen to the air compressor.

As already stated, the work of sinking the caissons was begun July 1 and continued without serious interruption until October 12, when the depth of cutting edge below low water was 52 ft. 9 in., with air pressure 23 pounds per square inch. At this depth the pressure on the longitudinal walls was so great as to show some bending of the middle transverse bracing, and as bed rock was found at a depth of 1 ft. 9 in. only below the cutting edge at this stage of the work, it was deemed advisable to attempt no further sinking of the caisson. The working chamber was filled in the following manner: A solid concrete wall was built in the middle of the caisson at a weak point, with the bottom of the wall carried down to the first ledge of limestone. Excavation was then made from the entire cutting edge to bed rock and the whole carefully sealed with concrete. This was done in 10 ft. sections by first carefully cleaning away all *debris* of the soapstone ledge and the thin ledges of limestone overlying the bed rock, and putting in the concrete—the cement used being Alsen's German. After the entire cutting edge had been carefully sealed in this manner the entire working chamber was thoroughly cleaned out with great care.

The soapstone edge and the first two thin layers of limestone which overlaid the bed rock of limestone were entirely removed. The working chamber was then completely filled with concrete, leaving no voids or interstices. The concrete shaft and air lock were then filled with concrete, using for both the working chamber and for the latter Louisville cement.

The pneumatic work of the Ohio caisson was finished on October 31, at 4 P. M., the masonry of the pier being 22½ ft. high. The caisson rests on bed rock, and its position is precisely right. It was originally placed 12 in. up stream, with the anticipation of its being drifted that much down stream before work was completed, and the expectation was exactly realized.

The *resume* of the work is as follows:

Launched June 2.
Sunk to bottom June 20.
Began sinking caisson July 1.
Stopped sinking caisson October 12.
Completed October 31.
Time of sinking, 104 days; or 6 inches per day on the average from low water.
Total time occupied 133 days, from time caisson was sunk until completed.

Quantities in Ohio caisson and crib:

527,500 feet B. M. of timber.
3,648·6 cubic yards concrete.
155,295·5 cubic feet displacement, or 5,276·6 cubic yards.
4,651 barrels of Louisville cement.
496 barrels Alsen's German cement.
Cutting edge 52 ft. 9 in. below low water.
Bed rock 54 ft. 6 in. below low water.
Bed of river to cutting edge 45 ft. 9 in.

KENTUCKY CAISSON.

The Kentucky caisson was launched on the 10th of June in the same manner as that for the Ohio end of the 550 foot span. On July 10 it was put in position beyond the protection piles with the deck complete. On July 13 the concreting of the crib was begun, and on July 16, with seven courses of the crib complete, containing 311 cubic yards of concrete, the displacement

of the upper end was 10 ft. 2 in., and that of the lower 8 ft. On July 21 the false bottom was entirely out and caisson nearly full of water. In this position it was found to rest on a nest of sunken logs, some of them 2 ft. in diameter, running under the cutting edge. The cutting out of these logs was at once begun, and was necessarily found to be somewhat tedious and troublesome.

They were cut into small pieces and taken out through the excavation shaft in buckets. This work was completed on July 28. The presence of these logs occasioned the loss of about two weeks in sinking the caisson. In other respects the sinking of this caisson was quite similar in all its features to the other. The material passed through was sand, gravel and large bowlders, being apparently through the original bed of the river after getting down some 20 ft.

The *resume* of this portion of the work is as follows:

Launched June 10.
Sunk June 11.
Began sinking August 5.
Began crib July 10.
Completed crib September 8.
Began concreting July 13.
Completed concreting September 15.
Reached bed rock October 27.
Completed work November 8.
Total working days from time of location, 120.
Days employed sinking, August 5 to September 27, 93 days.
Days employed on crib, 60; average, 0·59 ft. per day.
Days employed on concrete, 64; average, 0·55 ft. per day.
Average per day sinking, August 5 to September 27, viz.:
Distance bed rock to low water, 53·5 ft.; average, 0·575 feet per day.
Distance bed rock to bed of river, 42 ft.; average, 0·451 ft. per day.

CONTENTS.

514,683 ft. B. M. timber.
3,569·73 cubic yards concrete.
154,383·73 cubic feet displacement.
5,155·735 cubic yards volume.
4,550 barrels Louisville cement.
450 barrels Alsen's German Portland.

The Kentucky caisson remained in its first position about 12 in. up stream.

No delay, except two weeks cutting logs and a short delay owing to insufficient weight on top, was experienced. The work went on smoothly all the time and was a perfect success.

The heat in both caissons was at times very great, and a few men were disabled by the so-called "bends," but no lives were lost, nor were the men apparently injured from working eight hours each shift continuously.

The following is a succinct statement of the masonry built upon the cribs over the two caissons at the ends of the 550 ft. span:

Began Ohio pier September 24, 1887.
Completed Ohio pier June 30, 1888.
Began Kentucky pier September 17, 1887.
Completed Kentucky pier June 9, 1888.
Actual working days, about 130 Ohio and 140 Kentucky pier.
Rate per day, approximately, 7½ to 8 in. per day in height.

CONTENTS.

Limestone....	3,431·603	cu. yd.	Kentucky pier.
Freestone	1,465·910	"	" "
Oolitic stone..	66·150	"	" "
Total	4,963·663	"	
Limestone....	3,405·342	"	Ohio pier.
Freestone	1,398·680	"	" "
Oolitic stone..	66·150	"	" "
Total.....	4,861·172	"	

The total weights, including lumber in substructure, concrete, masonry, iron and steel of spans, timber floor of same and maximum moving loads, on the various abutment and river piers of this structure, and the loads carried per pile on the abutment piers and per square foot at bottom of caissons for the two river piers are as follows:

Ohio abutment pier, total weight.	13,202,324 lb.
Load per pile..................	77,200 "
Kentucky abutment pier, total weight..........................	13,890,224 "
Load per pile..................	81,200 "
Ohio River pier, total weight.....	36,719,285 "
Total load per square foot	13,000 "
Kentucky River pier, total weight.	36,922,285 "
Total load per square foot....	13,047 "

The above total weights, sustained by the two river piers, are the actual total loads, less the buoyant effect of the displacement, the volume of which is g.ven in the preceding data.

The pneumatic portion of the substructure, including all caisson and crib work, was performed by Messrs. Sooysmith & Co., during 1887 and 1888, in their usual efficient and successful manner.—*Trans. Amer. Soc. Civil Engineers.*

ECONOMICAL APPARATUS.

By WALTER H. INCK, Ph.D.

PIECES of apparatus which can be easily made and cost little for material are always in demand by those who have either limited incomes or who are at a distance from large business centers.

The following are descriptions of apparatus which can be made by any one who possesses a certain amount of ingenuity or mechanical skill. They are by no means to be regarded as temporary makeshifts; on the contrary, many of the pieces described may form trustworthy adjuncts to the furniture of the laboratory. A very little trouble expended may render them quite presentable.

BLOWPIPES.

A blowpipe for ordinary use may be made by boring a sound cork laterally three-quarters of its length, and then boring another hole transversely to meet the first in the center. At the shorter hole place a jet made of hard glass tubing drawn to a point, and at the other a longer piece of soft glass tubing, having the end smoothed by holding in the flame of a Bunsen burner (to avoid cutting the lips), and a bulb blown, as shown (Fig. A), to condense the moisture of the breath.

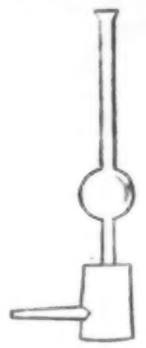


FIG. A.

FIG. B.

A burner to be used for this blowpipe may be made by partly closing the extremity of a piece of hard glass, as shown in Fig. B, attached to an ordinary gas jet by a piece of India rubber tubing.

A Herapath blowpipe, to replace the use of an air bellows, may be constructed by taking an ordinary

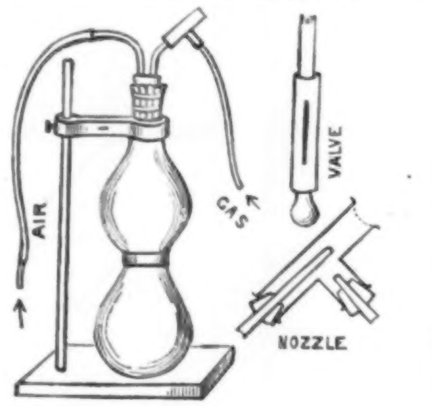


FIG. C.

bladder—which has been rendered pliant by rubbing with sweet oil—and placing an India rubber ring round the center of it, as shown in the annexed figure. In the mouth of the bladder a large cork, bored with two holes, is firmly tied. Through one of the holes a long glass tube is placed, reaching to the bottom of the bladder and fitted with a Bunsen air valve. This air valve can be made by taking a stout piece of India rubber and carefully slitting it about an inch lengthwise in the center with a sharp knife. One end is then drawn over the end of the glass tube, and the other closed with a piece of glass rod; this allows the air to enter the bladder, but prevents its exit. At the other hole in the cork is placed either an India rubber tube leading to a blowpipe, or the blowpipe itself fitted on a piece of bent tube. The nozzle can be made by fixing to an ordinary brass T-piece, by means of a cork, a tube for the blast of air, and at the other opening, at right angles to it, a similar but slightly larger tube for the gas. The India rubber band in the center of the bladder is to give it elasticity, and acts in the same way as the India rubber sheeting in the ordinary foot bellows. If a wide jet for the air supply be used with low pressure on the bellows, lead glass may be very easily manipulated with this form of blowpipe, and will not be found to blacken. If a fair pressure of water is at hand, a good blower may be made as follows:

A small bulb is blown in a piece of glass tubing about six inches long; this is pierced in the upper part

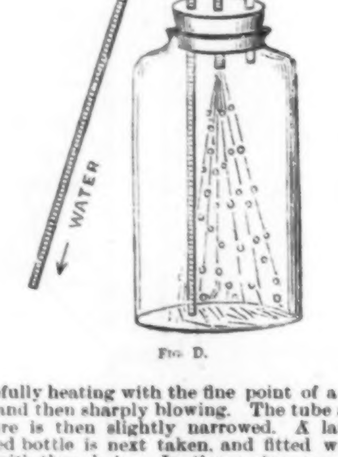


FIG. D.

by carefully heating with the fine point of a blowpipe flame, and then sharply blowing. The tube above the puncture is then slightly narrowed. A large wide-mouthed bottle is next taken, and fitted with a cork bored with three holes. In the center one the above tube is placed, connected with the water supply; in the second, a tube leading to the bladder reservoir; and in the third, a bent tube reaching to the bottom of the bottle, so as to act as a siphon. The water passing through the center tube draws with it air, which is forced into the reservoir, while the water is carried off through the siphon. If the water supply be not at hand, the lungs may be saved by filling the bladder by means of an ordinary kitchen bellows.

BUNSEN BURNERS.

The simplest of this class of burners may be made by bending a bit of ordinary glass tubing at right angles, and nearly closing one of the extremities. This is then inserted into a small cork bored in the center and notched at the sides, over which a slightly larger tube of hard glass is fixed. The free end of the tube may be supported on a large cork, or fixed into a cork supported on a glass funnel (see Fig. E).

FIG. F.

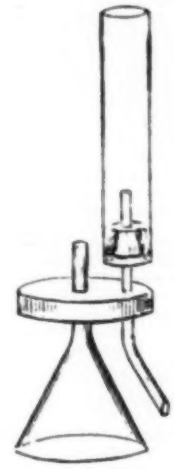


FIG. E.

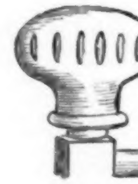


FIG. G.

Another very simple burner to be attached to an ordinary jet may be made by winding stout brass wire round a tube slightly larger than the gas jet, so as to make a coil about 2½ inches long; the inner core is extracted, and one end of the coil fixed over the burner, as shown in Fig. F. Instead of the brass coil a piece of brass or glass tubing may be fixed over an ordinary burner by means of two small wedges of cork at the lower extremity, allowing space enough for the air to enter at the sides.

An Argand burner may be made by filing slits in a hollow brass door-handle, at regular intervals, and attaching it to the gas supply (Fig. G). An ordinary

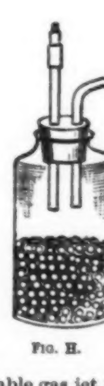


FIG. H.

FIG. I.

portable gas jet forms a good starting point for these burners, and may be obtained for 1s. or 1s. 6d. from any gasfitter. In lieu of this, a brass rod, at the top of which a jet has been screwed, may be placed in a bottle fitted with a cork with two holes; in the other hole an elbow tube is fitted for the supply of gas. The bottle is three-quarters filled with lead shot or sand, to make it steady (see Fig. H).

A spirit lamp is easily constructed by placing a bored

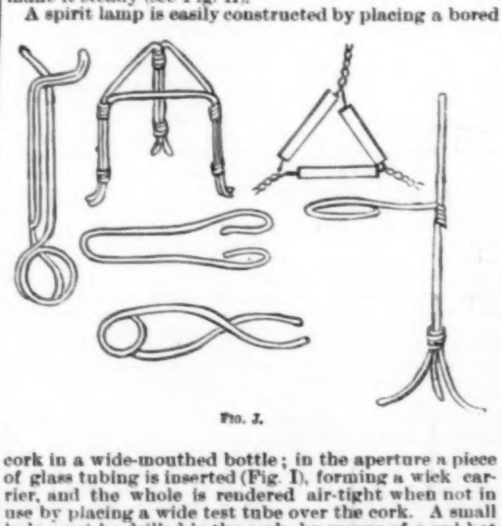


FIG. J.

cork in a wide-mouthed bottle; in the aperture a piece of glass tubing is inserted (Fig. I), forming a wick carrier, and the wick is rendered air-tight when not in use by placing a wide test tube over the cork. A small hole must be drilled in the cork, by means of a red hot needle or wire, to allow air to enter the bottle and replace the spirit consumed. The application of stout tinned iron or brass wire is practically unlimited in the

construction of laboratory apparatus. A pair of flat and round-nosed pliers with a file are all that is required for manipulating it. The formation of a Bunsen burner (Fig. F) has already been described. The following are hints which may be expanded at pleasure. Pinch-cocks, tripods, watch-glass holders, pincettes, test tube holders, filter rings may be mentioned among the many useful things which may be made from wire, as shown in the figures given.

STEAM APPARATUS.

A most useful, and often neglected, adjunct to a laboratory is ordinary composition lead gas piping, which for pliability, rigidity, non-compressibility, and cheapness, may vie with India rubber tubing. As a connection between vacuum pumps and desiccators it is unrivaled.

By carefully winding this tubing round a fairly wide glass tube, narrowed at one end, a most efficient condenser may be made, which acts quite as well as a jacketed Liebig's condenser, and if it be japanned it looks equally well. It is, moreover, easier to handle, and more convenient to attach to the water supply. Fig. K shows the arrangement. A hot water funnel,

FIG. K.

FIG. L.

or steam bath, may be made by winding the composition tubing spirally round a funnel (Fig. L), or in the form of a saucer, on which the evaporating basin may rest. Steam required for this form of apparatus may be generated from a tin flask or can, such as a work man's tea flask. A steam drying cupboard may be constructed by laying a coil of the composition tubing on the bottom of a box, such as is shown in Fig. M, and conducting both ends through holes bored in the

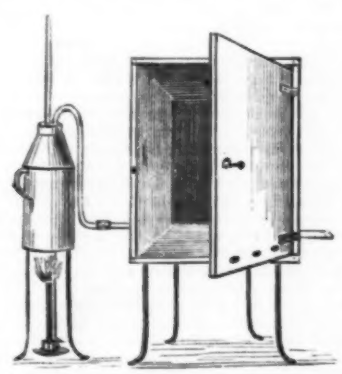


FIG. M.

sides of the box to the outside. Steam passed through this coil heats the whole apparatus to about 190 to 200° F., which is quite hot enough for ordinary drying operations, such as drying filters, precipitates, etc.

The steam required for one of the above pieces of apparatus will be found to be sufficient for all three, passing it first through the drying cupboard, then through the evaporating pan coil, and, lastly, through the filter warmer. It can then be led off through a condenser, and used in the laboratory as distilled water.

WOOD REQUISITES.

The manipulation of wood requires more skill and a few more tools, yet the following will be found by no means difficult to make.

A test tube holder (Fig. N) can be made from two

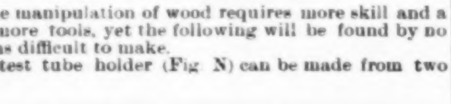


FIG. N.

pieces of soft wood. One square piece, 6 inches long, is rounded for 2 inches at one end, and at one-eighth inch from the other end a curve is cut to hold the test tube and prevent it from slipping. The clamp part is formed from a similar piece, but only 4 inches in length, 2½ inches of which are beveled off in the shape of a wedge, and on the same side a curve is cut corresponding to the curve on the first. The two are joined together by a stout India rubber ring, as shown.

A retort or burette stand (Fig. O) can be made as follows: On a soft wood or deal base an upright of straight close grained wood about 1 inch wide by one-half inch thick is firmly fixed. This is cut with a wide saw three-quarters down its length, dividing the upright into two equal one-half inch squares. An inch below the cutting a screw is fixed to prevent the wood from cracking and the cutting from extending. At the top the two squares are joined together by a screw having a thumb piece to enable it to be loosened or tightened at will. The clamp part is made by bending a piece of stout tinned iron plate, 10 inches by 1 inch, in half, and hammering the joint, thus making two arms 5 inches long. The ends are then bent in rather less than a half circle, to catch any round object which they are destined to hold, and lined with cork. An ordinary brass curtain ring is then hammered so as to form an elongated oblong, and slipped over the clamp. By altering the position of this ring the jaws of the clamp may be extended or contracted. The top screw of the upright is then loosened, and the hammered end of the clamp placed within the slit; on tightening the screw the two sides of the upright will be forced to-

FIG. O.

gether, and securely fix the clamp in a rigid position. If the clamp be required to be elevated or depressed, all that has to be done is to loosen the top screw, place the clamp in the desired position, and again screw up tight. The whole apparatus may be then stained and the metal parts japanned, which will give it a neat appearance.

CHEMICAL APPARATUS.

Among the many simple forms for the constant supply of sulphureted hydrogen, carbonic acid, or hydrogen, the two following may be mentioned: A 6 oz. wide mouthed bottle (Fig. P) is fitted with a good cork, bored with two holes; in one a delivery tube is fitted, and in the second an upright tube, having a large bulb blown in the center, reaching to the bottom. The

FIG. P.

FIG. Q.

bottom of the apparatus is covered with coarse pieces of glass, and the generating substances placed on this layer. As soon as the stream of gas is cut off by closing the exit tube, the acid is forced into the bulb, and the evolution of gas ceases.

A second form consists of a wide mouthed tube, such as a small lamp glass, closed at the lower extremity with a paraffined cork which has been perforated with four or more holes (see Fig. Q). The sulphide of iron, marble, or zinc, as the case may be, is then placed in the tube, and the other end closed with a well fitting cork, supplied with a delivery tube.

This is then placed in a wide mouthed jar half filled with diluted acid; on stopping the current of gas the acid is forced out of the lamp glass, and consequently the generation of gas ceases till the delivery tube is reopened, when the acid flows into the inner tube, and the action recommences.

A gas holder, which may equally well be used for an

FIG. R.

aspirator, can be made by connecting two Winchester quarts by means of an India rubber tube (Fig. R). Each bottle is fitted with a cork in which are placed two tubes bent at right angles, one reaching to the bottom of the bottle and the other to the base of the cork. The rubber tube connects the two long tubes; when the liquid is required to flow from one to the other, the full bottle is raised, the liquid siphons over into the lower bottle and forces out the gas contained therein. If, however, the apparatus is required as an aspirator, the tube to be aspirated is attached to the shorter of the two tubes of the full bottle, and the other lowered; the water flowing from the upper to the lower bottle causes a diminution of pressure, and thus induces a current of air.

Out of a Winchester quart a serviceable percolator may be made by removing the bottom (Fig. S). This is accomplished by touching the side with a piece of red hot glass rod at any place at which a division is required. This starts a crack which may be led in any desired direction by the careful application of a hot rod. A certain amount of practice is required to carry this out in a satisfactory manner. When the bottom has been removed the sharp edges are roughened by an application of a file, and the percolator, reservoir or gas jar is ready for use. There are other methods of removing the bottoms of bottles, but none is so safe as the one described. Generally the bottom will come off pretty evenly by letting a poker or heavy iron bar fall vertically through the mouth. Another way is to wrap a strip of wet filter paper round the part to be

FIG. S.

severed, and plunge the bottle evenly into boiling water up to the paper line. Bottles and wide tubes may be divided by wrapping wet filter paper evenly round the glass on either side of the desired line of division, leaving a quarter of an inch free. This free space is then heated in a Bunsen flame, and on giving a sharp blow or pull the glass will generally sever along the heated portion, but this is by no means an infallible or reliable method. Broken flasks and retorts may be converted into serviceable evaporating basins by leading the crack with the aid of a heated glass rod within two inches, more or less, of the bottom, and then horizontally, so as to cut off a saucer-shaped vessel. The edges are then rounded in the blowpipe, and a lip made by strongly heating the edge at one point, which, when the glass is softened, is slightly forced outward with a piece of warmed metal, such as a knife blade.

Drying tubes for pumice stone and sulphuric acid (Fig. T), having a compact and neat appearance, may be made in the following way. Take a soft glass tube

FIG. T.

about 12 inches long and ⅜ inch internal diameter, heat strongly in the blowpipe 5 inches from either end till red hot, and cautiously pull out, making two constrictions, care being taken not to let the glass in these two places be too thin. Then heat between the two narrowed portions, when white hot remove from the blow pipe and slowly pull the tube apart, always revolving during the application of the blowpipe flame.

Thus two tubes are produced. By careful heating and blowing, round off the bottom of each tube, leaving the glass as thick, if possible, as the rest of the tube. Take a cork and bore one small hole in the center and one at the side; in these two holes fit two glass elbow tubes, the center one running down past the narrowed part into the bulb below, the other going just below the cork.* The cork is then partially removed to allow the insertion of the pumice, which must be in pieces about the size of a small pea, and no very small portions or dust must be placed in the tube. Sulphuric acid is then poured in through a small funnel, and the cork replaced. The excess of sulphuric acid will collect in the lower bulb and may be forced out by blowing down the shorter tube. A very little practice will enable any one to make these drying tubes. The only difficulty in their construction is the formation of a neat bulb beyond the narrowed part. They may equally well be used for gas washers or absorbers.—*Chemist and Druggist.*

"COMPRESSED AIR" SHEEP SHEARER.

THE recent sheep-shearing machine trial, which extended over three days, was probably the most exhaustive test that any machine has been subjected to for many years.

The agricultural society of N. S. W., to whom the credit belongs of initiating and carrying out this trial, used every care and precaution to insure a fair contest,

FIG. 1.—AUSTRALIAN COMPRESSED AIR SHEARER.

and the decision of the six judges must be accepted as placing the relative merits of all the machines beyond dispute.

Recognizing that a sheep-shearing plant to be effective must not only insure good shearing, but must be mechanically correct, the agricultural society chose as judges three practical squatters and three leading engineers, and on the decision of these six gentlemen, the government national prize valued at £30, and the pastoralists' prize of £25, has been awarded to the Australian compressed air shearer (Suckling and Martin's patent).

Each competitor was given a number of sheep, and at eight minutes past eleven the whistle was blown to commence work, which was continued until eight minutes past one. After lunch the time test was continued for two hours more, and when time was called

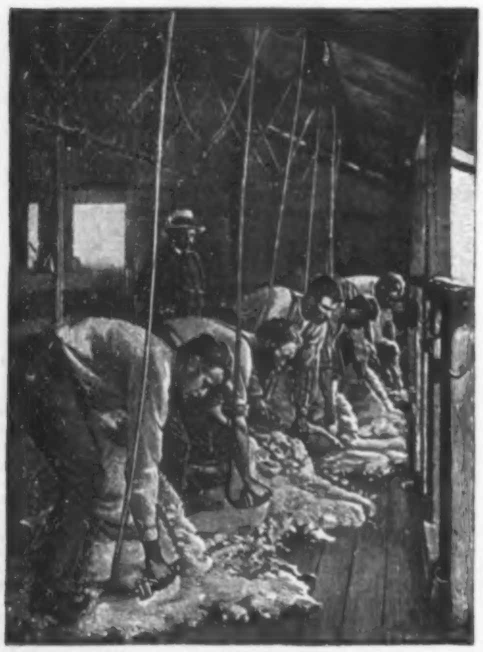


FIG. 2.—THE COMPRESSED AIR SHEARER AT WORK.

the Australian compressed air shearer had 43 to its credit, being an average of say eleven shorn sheep per hour.

This was known as the practical or working test, and the Australian compressed air shearer was awarded 61½ points out of a possible 660 for work done.

In the Australian compressed air shearer every advantage is taken of the most recent improvements, and the air compressors are manufactured for the company by the well known house of Ingersol, of New York.

All that is necessary for a compressed air shearer plant is a boiler, compressor, receiver and air pipes. The air supply pipe is ordinary black pipe, and the rubber hose which conveys the air to the shearer is simply a length of three-eighths inch garden hose.

No shafting, pulleys, belts or gearing of any kind are required, and what is of equal importance to the

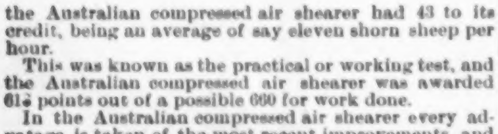


FIG. 3.—POSITION OF THE COMPRESSED AIR SHEARER WHEN AT WORK.

squatter, almost no expense is necessary in fitting up a shed for compressed air, as no posts or strengthening of the building are needed, the air pipe being fastened or hung in any desired position, and the compressor can be at any distance from the wool shed.

Indeed, so simple and easy in fixing are the parts of the compressed air shearer plant that inquiries are now being made for portable plants. So an enterprising man will now be able to travel with his compressed air shearing plant from station to station in the same way that a thrashing machine is traveled from farm to farm.

The sheep are not cut or injured, it is estimated that from six ounces to ten ounces more wool per sheep is taken off with it than with the hand shears; the wool is shorn without second cuts, and the quantity of locks is reduced.

The Australian shearer cannot get hot, but on the contrary, as it is worked by cold air, the machine is much cooler in work than when idle. All the parts are inclosed in a casing, so there is no projection or tension screw to catch in and injure the fleece.

The rubber hose that conveys the air to the shearer is perfectly flexible, so the shearer works all round his sheep (instead of having to keep shifting the sheep to suit the machine.—*Home and Farm.*

AN IMPROVED FUSE CAP FASTENER.

THE device shown in the illustration, which has been patented by Mr. N. W. Moodey, of Fresno City, Cal., is especially designed as an improved implement for fastening the caps on fuse employed in exploding giant powder. The pliers are formed of two similar parts, connected by the pivotal rivet, each part having a cheek with notches, at the sides of which are cutting edges for cutting the fuse. The curved jaws beyond the cheek pieces, when closed, form a circular

MOODEY'S FUSE CAP FASTENER.

aperture, around which the jaws are beveled, one jaw having a tongue which fits in a groove in the other jaw. The pliers are employed for contracting the end of the cap on the fuse firmly and absolutely watertight, thus avoiding the dangerous operation of digging out wet and unexploded loads.

THE ARTIFICIAL LIGHT OF THE FUTURE.*

By Prof. E. L. NICHOLS,
Professor of Physics, Cornell University.

THE growth of electric lighting forms one of the most brilliant chapters in the history of invention. The record is one of which the electrician has reason to be proud. It is a record of advance following advance in our means of generating current and of transmitting it. It is the record of the evolution of the arc lamp from the first crude forms to the perfectly regulated lamp of to-day. It is the record of the development of the incandescent lamp. Throughout it all we note with wonder that the perfecting of 10,000 details of construction has gone hand in hand with ever-diminishing cost of production.

As we review the history of the electric light, however, we find that in two respects there is less cause for congratulation. When we come to consider the quality of the light produced and the efficiency of the apparatus as a light-making machine, we find that the incandescent lamp of to-day produces the same quality of light which the earliest examples of its type were capable of giving. We find, however, that its light differs but little from that obtained by burning oil and gas, which, in turn, in spite of all the improvements which have marked the growth of artificial illumination, is almost the same in quality as that which the Eskimo obtains from the crude blubber of the whale, or which the dweller in the log cabin on the frontier may get from his home-made tallow dip.

It is true that the efficiency of the incandescent lamp has gradually risen from five to three watts per candle, but those who have had occasion to trace the discouraging life curves of such lamps, may know how little real progress the change implies. We may start a well manufactured lamp at any temperature we please, provided we do not pass a certain limit, beyond which the life of the lamp would be too seriously curtailed. The initial efficiency may be made as large as we please, within that limit; but it is only a question of a few days or hours when the lamp will have dropped to the dead level of mediocrity, the five watt level which seems to mark the confines of permanency in the case of incandescent carbon.

When we take a lamp and raise its electromotive force step by step, measuring the current, voltage and candle power at each stage of the experiment, and plot the curve which expresses the relation between the energy required and the light produced, we are gratified at the marked rise in efficiency which follows each slight increase in the temperature of the filament. That rise of temperature, however, means shortening of the life of the carbon, is well known. Mr. John W. Howell, in a valuable paper read before the American Institute of Electrical Engineers,† has given us abundant data upon that point. Unfortunately, rise of temperature means much more than that. I will venture to show you a few life curves recently obtained in the laboratory of Cornell University. These curves enable us to see at a glance what happens during the curtailed existence of a lamp which is forced to undue brilliancy. I introduce them because they indicate very definitely the nature of the difficulties which confront us when we endeavor to increase the efficiency of an incandescent lamp by raising its temperature.

In the first instance, a lamp was started at the candle power indicated by the maker, and was held at constant voltage by means of the current from a storage battery. The initial candle power was 16, which was obtained at the expenditure of 3.015 watts per candle. Measurements of electromotive force and current were made at intervals of about 10 hours, during the 800 hours that the lamp lasted. The candle power was redetermined at intervals of about 100 hours. The voltage never rose more than 0·65 volt above the initial value, and then only for a short time. The average electromotive force of the entire run was 0·40 volt below the initial value. The record of this lamp represents an individual case, and not the average obtained from many lamps, but it is typical of the results which have been obtained with many. The characteristic features are rapid followed by slower falling off in candle power, the decrement amounting finally to more than 50 per cent., and rapid followed by slower falling of efficiency, to a final value of 5·75 watts per candle. These changes were accompanied by continuous and marked increase in the resistance of the filament.

If it be asked whether this individual case represents a state of affairs common to all incandescent lamps, I can only say that in my experience, which is certainly much less extensive than that of some others, I have known of no class of lamps, the performance of which did not agree approximately with that indicated by these curves. Mr. W. H. Pierce,* who described extended tests of the initial and average efficiency of incandescent lamps in a paper read before the Institute of Electrical Engineers some time ago, recorded no exception to this rule of decreasing candle power and efficiency with time.

This falling off in candle power exhibited by lamps maintained at constant voltage can be met by a procedure not easily applicable perhaps in commercial work, but readily carried out where the object in view is simply to study the behavior of the lamp under unusual conditions. The method consists in raising the electromotive force at short intervals of time by amounts sufficient to restore the candle power to its normal value.

Under this treatment the life of the lamp in question was not quite 100 hours. The total rise in electromotive force during the test amounted to about nine volts; the efficiency decreased from 3·118 watts per candle to 3·468 watts per candle. The resistance of the filament rose from 221·6 to 234·8 ohms. During the first 50 hours the changes were slight, then occurred a sudden increase of resistance, accompanied by marked rise in electromotive force and in amount of energy consumed.

The life history of the incandescent lamp at still higher temperatures does not differ essentially from that which we have just been considering, but the changes in question go on much more rapidly.

The conclusion to be reached from these data, and from the great mass of experimental results which has accumulated since the incandescent lamp has become an object of investigation, is only too evident. The efficiency of an illuminant in which carbon is the glowing material is a function of the temperature. It appears that the incandescent lamp is fairly stable only at temperatures for which its efficiency does not exceed about five watts per candle. We have just seen what occurs when one attempts to maintain lamps at degrees of incandescence corresponding to a much higher temperature. It is, perhaps, not possible to point out with perfect definiteness all the causes that are at work to reduce the candle power. The black coating which gradually forms on the interior of the lamp bulb intercepts more and more of the light from the filament as the age of the lamp increases. The growth of this film and its power of absorbing light have recently been carefully studied by two of my advanced students, Messrs. B. E. Moore and C. J. Ling.

The life curves which I have shown were made by them as a necessary part of their investigation of the loss of light due to the opaque film, and I will venture to take from their work, as yet unpublished, the results which they have obtained. They show the amount of light of each wave length of the visible spectrum which the coating on the interior of the bulb absorbed. The measurements were made after the lamp had been in operation 100 hours, 200 hours, 400 hours, and 800 hours. Abscissæ are wave lengths and ordinates show the amount of light transmitted by the lamp bulb at the above mentioned times, in terms of the amount which the bulb allowed to pass before the coating began to form. The absorbing power of the film was very nearly uniform throughout the spectrum, so that the blackening of the lamp had no appreciable effect upon the light which it emitted; also the absoption at the end of 200 hours was considerably more than half as great as that at the end of 800 hours, and the total loss of candle power due to blackening was about 22 per cent.

These measurements enable us to account for rather more than one-third of the loss of candle power suffered by the lamp. We are not with our present knowledge in position to speak so definitely concerning the other two-thirds, but the increase in the resistance in the carbon indicates another source of diminution. That gradual failure of the vacuum which the use of the spark coil would unquestionably have enabled the observers to detect, may well be answerable for the rest. Now, the temperature of an incandescent lamp filament at five watts per candle is very nearly the same as that of the carbon in the light-giving flames produced by the combustion of oils and gas, and it appears that the attempt to pass this temperature introduces difficulties of such a nature as to lead to the serious question whether we have not reached a definite limit, beyond which incandescent carbon ceases to be permanent.

At that limit the efficiency of the lamp is very small indeed, 95 per cent. or more of the radiant energy emitted being of wave lengths too long to afford light.

As to the arc light, no more encouraging report can be made. On the contrary, it is perfectly well established that the quality of the light, instead of increasing, has fallen off, in the course of the development of the lamp from the clockwork regulators of Dubosc and Foucault, with their slender carbons, to the commercial lamps of to-day.

The researches of Nakano,† Marks,‡ and others show that the efficiency of the arc is a definite function of the current density of the terminals of the carbons, in-

* Abstract from a recent lecture before the Electric Club, New York.

† John W. Howell: Transactions of the Am. Institute of E. E., vol. v., p. 237.

* W. H. Pierce: Transactions of the American Institute of Electrical Engineers, vol. vi., p. 293.

† Hatsane Nakano: "Am. Institute of E. Engineers," vol. vi., p. 308.

‡ Louis B. Marks: "Am. Institute of E. Engineers," vol. vii., p. 175.

creasing nearly in inverse ratio to the cross section of the pencil.

When the maximum current capacity of the latter has been reached, the efficiency is in the neighborhood of 10 per cent., a value which is not likely to be greatly exceeded by any of the methods in vogue at the present day.

As Mr. Edward Weston * says, in his discussion of Nakano's paper on the efficiency of the arc lamp:

"The small amount of luminous energy compared to the total energy employed is a sad thing always."

In the vast accumulation of experience which the past years have witnessed, nothing has come to general knowledge which looks to the raising of the barrier which blocks our progress. It seems only too probable that the limiting temperature at which carbon can be used for the production of light has been reached, and with it the maximum efficiency of artificial illumination.

The phenomena observed whenever we attempt to raise carbon above what may be termed its normal temperature of incandescence are significant, and they all point in one direction. We have just seen that when we raise the voltage of an incandescent lamp, we gain splendor of performance at the cost of permanence and stability. I might remind you, in this connection, that when the heat of gas flames is increased by forced draft, they become non-luminous; that the magnificent illuminating power of the arc lamp is not due to the intensely hot electric arc itself, filled though it be with carbon in process of transfer from the positive to the negative pencil, but to the cooler carbon terminals. Such are the facts with which we have to deal when we consider the problem of increasing the efficiency of illumination by carbon, whether by direct combustion, by incandescence in vacuo or by the use of the electric arc. In the face of the many unexpected things that have been accomplished through the agency of electricity, he would be rash who asserted that the possibilities of carbon had been exhausted. In view of the achievements of the time one is not permitted to declare the case hopeless. Nevertheless, the outlook is not an encouraging one.

If, in what I have said thus far, I have drawn what seems to be a gloomy picture, it is not because I fail to recognize the importance of the electric light of to-day as a factor in our civilization. Its superiority over other methods of artificial illumination is so well understood that it need not be enlarged upon here. Of its advantages we hear on every hand. Of its limitations we hear less, and yet a knowledge of the latter is quite as important to those who are interested in its further development. The waste of 90 or 95 per cent. of non-luminous energy in the production of light is a matter to which we are apt to give little thought, and when the economic importance of the fact has been forced upon us by the study of the recent investigations, which have been made to establish it, we find consolation in the thought that, after all, those percentages are somewhat larger than the corresponding values for candles, oil and gas.

As time goes on, however, the question of the efficiency of illuminants will increase in practical importance.

No one of us, I take it, is of the opinion that the world will always be content with the present extravagant methods of obtaining light. Progress in these matters is chiefly a question of the careful and exhaustive study of the properties of the substances with which the inventor and engineer have to deal. As in the past, so to-day and in the future, researches in the laboratory must prepare the way for operations in the workshop and manufactory. I have thought it not without interest, therefore, to discuss the behavior of incandescent carbon under conditions, some of which are not "commercial," and to attempt to point out the significance of that behavior. Now, if you will permit me, I will turn toward the future and consider the properties of some other sources of light, with the view of inquiring whether they may not have a part to play in the artificial lighting of days to come.

What is to be the light of the future?

From the standpoint of the engineer, I will frankly say that I cannot answer that question, but abandoning the directly practical point of view, there is something to be said.

I need offer no apology here for presenting facts the application of which is at best remote, and the present importance of which is, therefore, rather scientific than utilitarian, nor need I remind you that all the so-called "forces of nature" which have been yoked and impressed into the service of man were the object of scientific curiosity and the subject of scientific investigation long before the idea of a practical application was entertained.

The number of elements and of compounds capable of sustaining a high temperature without dissociation or change of state is very large. Carbon is the only one of these, the capabilities of which as a source of light can be said to have been fully tested, and yet all the others, when heated to a proper point, emit light-giving radiation. Take for example the metallic oxides.

We heat the oxide of calcium in our magic lanterns, and it gives us a light of great intensity and but little inferior to the arc light in whiteness. The exceeding clumsiness of our method of rendering it incandescent, however, has prevented its adoption excepting for certain special purposes.

MAGNESIUM LIGHT.

We burn magnesium in fire works and for photographic flash lights, and occasionally we indulge in the luxury of igniting a bit of the ribbon and admiring for an instant the intense brilliancy of its flame. Now, magnesium is one of the most abundant elements on the face of our planet. It is a rather costly metal at present, being quoted at 50 cents an ounce in this country and at about half that price on the continent of Europe.

Even under the limited demand for it which exists at present, it has fallen to about one tenth of its price of a few years ago, and I feel sure that it lies within the power of the electrician to greatly further reduce the cost of production. Among artificial illuminants, magnesium has in one respect no equal. W. H. Pickering, who studied its spectrum in 1880, found it to approach sunlight in quality even more closely than the electric arc light does.*

The magnesium flame is about ten times brighter in the violet than a gas flame of the same power, and but little more than half as strong in the red. It will be seen also that it surpasses the electric arc everywhere beyond the yellow, save in a very limited region of the extreme violet. In order to appreciate fully the significance of these curves, one must have had occasion to compare the various lights to which they refer, placing them side by side and noting the effects. You are all aware that the magnesium light is very white and very powerful, but unless you have happened to see it in direct competition with our ordinary illuminants, you will be but dimly conscious of the difference between them.

I have here a single magnesium lamp of European manufacture. By means of a simple arrangement of clock work, it feeds a thin magnesium ribbon at a rate just sufficient to maintain a flame of between 40 and 50 candle power. Turn your attention for a moment to the screen just behind us. It gives you the impression of a nearly uniform white surface, which is well lighted by the incandescent lamps with which this hall is so abundantly supplied. Its whiteness now, however, is a very different thing from that which it will take on under the rays of the magnesium light. I light the little clock work lamp, placing it so that it illuminates a portion of the screen. That part which is shaded from the lamp is just as well lighted as it was before, and its tint is in no way changed; but no one would be likely to describe it as a white surface under the present circumstances. It has sunken by comparison into a rather weak chocolate brown. Let us turn the lamp so that you can see the burning magnesium, and place beside it, to emphasize the contrast, this lighted candle. How dull and sickly the candle flame appears, and yet, though old-fashioned and rather out of date among our modern glow lamps, the candle does not suffer greatly, so far as quality of light goes, by comparison with them.

I have been much interested in studying this source of light, and I will venture to give you some of the results which I have obtained. This lamp consumes 168 milligrammes of magnesium per minute. It is difficult to determine its candle power by ordinary methods, because of the enormous difference between the color of its light and that of gas light. By means of measurements made with the horizontal slit photometer, an instrument the use of which entirely obviates this difficulty, I found the light to average slightly more than 40 candle power. Assuming 40 candles to be the correct value, we have 4·2 milligrammes of magnesium consumed per minute per candle. Now, to maintain one candle power of gas light one minute with an average quality of illuminating gas, 137 milligrammes of gas must be consumed. With gas at $1 per 1,000 cubic feet and magnesium at $10 per kilogramme, a price which is in excess of the present European rate, the magnesium light would cost, candle for candle, about 6·72 times as much as gas. With magnesium at $1.49 per kilogramme, or about 67 cents per pound, the cost of the two illuminants would be the same. Looking at the matter from a slightly different point of view, we may say that since 4·2 milligrammes of magnesium will give as much light as 137 milligrammes of gas, their relative productiveness as illuminants is as 32·1 to 1. The true relation between their values is, however, expressed by a larger ratio than that, since, candle power for candle power, the real worth of a source of light increases with its temperature. The total luminosity of the arc light, for instance, may be considered fully 25 per cent. greater than that of gas. Two candle power of sun light is the equivalent of three candles of gas light. The luminosity of the magnesium light lies between these two values.

The proper way to compare sources of illumination is to determine their net and gross efficiencies; by which I mean, respectively, the ratio of total radiation to light-giving radiation, and the ratio of the total amount of heat set free in the process of producing a candle power of light to the heat energy represented by the light itself. Now, the heat equivalent of a candle power of gas or of the light of an incandescent lamp at five watts per candle is about 3·6 gramme-calories per minute. The total heat of combustion set free in generating a candle power of gas light has been variously estimated at amounts ranging from 971 gramme-calories per minute (Preece) to 4,100 gramme-calories (Thomsen). Calculations based upon the theoretical heats of combination of illuminating gases give values nearer the latter than the former amount.

The amount of heat set free when a gramme of magnesium is converted into the oxide is very much less than that resulting from the combustion of a gramme of coal gas, and the light obtained is, as we have just seen, more than 32 times as great. The gross efficiency of the magnesium light must, therefore, be many times higher than that of gas light. To be exact, we find, if we adopt the value given by Thomsen † for the heat of combination of magnesium (6077), that the magnesium flame of one candle power should generate only 25·52 gramme-calories per minute. Taking the very low estimate of 1000 gramme-calories per minute for gas, *we find the gross efficiency of the magnesium flame to be about forty times that of gas light.*

The simplest method of determining the net efficiency of a source of light is that recently applied by Mr. Merritt to the study of the incandescent lamp.‡ I have measured the efficiency of the magnesium flame by Merritt's method, which consists in receiving the radiation upon the face of a thermopile. A glass cell containing a solution of alum is placed between the flame and the pile. This cuts off almost all those rays which do not produce light and permits about 75 per cent. of the luminous waves to pass. After observing on a suitable galvanometer the deflection produced by the light-giving radiation, the cell is removed and the deflection noted again. The ratio of these two readings, properly corrected, gives the net efficiency of the source of light. In the case of the magnesium flame, at least 15 per cent. of the total radiation was found to belong to the visible spectrum. Let us consider the matter from another point of view. When we disperse the rays from any source of light by passing them through a prism or reflecting them from a diffraction grating, we find that we have to do with a great many rays which are of a wave length too great to affect the eye. These constitute what is called the heat spectrum, and they are accompanied by a few rays which are of the wave lengths capable of optical action. By means of the thermopile or the bolometer, it is possible to explore the whole spectrum, and to determine the intensity of the radiation of each wave length which the source emits. From these values the curve of distribution of heat in the spectrum may be plotted. The curve consists of two parts: That which gives the energy of the light-giving rays and that which shows the amount of radiation outside of the visible spectrum. The ratio of the areas inclosed by these two portions of the curve is the net efficiency of the source of light. Such curves for the flames of candles, oil, and gas show that less than two per cent. of the total radiation is luminous. In the case of the incandescent lamp the amount rarely exceeds five per cent. The arc lamp contains about ten per cent. of useful rays. The magnesium light, therefore, according to the data which I have just presented, possesses a much higher net efficiency than any of the other sources of artificial illumination. To what does it owe its superiority?

We have seen that, weight for weight, magnesium affords more than 30 times the light obtained from gas, with the development of much less heat. The quality of the light is such that merely from the standpoint of illuminating power, to say nothing of the additional æsthetic value of a light which approaches sunlight in whiteness, each unit of it must be regarded as the equivalent of rather more than 1·25 units of gas light.

The character of the light corresponds to a temperature much above that of the electric arc, but the flame does not seem to be very hot. I have not as yet succeeded in obtaining a satisfactory measurement of the flame temperature, but a preliminary test, made at my request, gave approximately 1,400° C. This value, which is presented subject to correction, enables us to classify the magnesium flame, at least placing it among those the temperature of which is far below the melting point of platinum. Its temperature, probably, does not differ widely from that of the luminous gas flame.*

The large candle power of the magnesium flame is due to its peculiar structure. A gas flame consists of a column of heated gases, the particles of which are rising rapidly from the jet of the burner. These carry off with them, by convection, 80 per cent. or more of the heat of combustion. The flame owes its luminosity entirely to the fact that near the base of the column a few particles of carbon, as yet unoxidized, are heated to incandescence. The total radiating surface of these particles is very insignificant compared with the apparent superficial area of the flame; it is, indeed, not very different in extent from the radiating surface of the filament of an ordinary incandescent lamp of the same candle power. The constitution of the magnesium flame is very different. The product of combustion is the oxide of magnesium, a white, amorphous solid of considerable density; it is, indeed, fully twice as heavy as the metal itself. The oxide remains, for the most part, in the place where it was first formed. It becomes intensely incandescent, and having large radiating surface, it affords a large amount of light. Under such conditions, convection plays a minor part, and that which is the chief source of loss in the production of light by direct combustion of gaseous fuels is avoided. The gross efficiency is, therefore, very large.

The question of the *character* of the radiation from the magnesium flame offers greater difficulties. It is certain that neither platinum nor carbon at any temperature to which they can be subjected in practice will give anything approximating to the quality of the magnesium light. I am convinced that we have to do here with a very different law of radiation from that which governs ordinary cases of incandescence. Taking carbon to represent the normal state of affairs, we may say that the radiation of magnesium oxides is out of all proportion to the temperature of incandescence, also that the percentage of those shorter wave lengths which furnish green, blue and violet light is abnormally large. That the radiation of the magnesium flame comes in part under the head of what Professor E. Wiedemann has termed "luminescence" I have little doubt. This word covers all those interesting phenomena known as phosphorescence, fluorescence, etc.

LUMINESCENCE.

Luminescence is supposed to be due to a different class of molecular vibrations from those which cause ordinary incandescence. One of the characteristics of this class of vibrations is that it tends to produce selective radiation; that is to say, radiation in which a single wave length or set of wave lengths predominates. Another characteristic of luminescence is that it is frequently, perhaps always, the result of previous treatment to which the glowing body has been subjected. This previous process may have been nothing more than the shining of the sun's rays upon the luminescent surface, as in those cases of phosphorescence concerning which Becquerel has taught us so much.† It may have been in the course of some chemical reaction or process of crystallization that the body received its preparation. In such cases the power lies latent until it is disengaged by the action of some external force.

The immediate exciting cause may be mechanical, electrical or thermal. In the last case, which most directly concerns us here, a certain rise of temperature is necessary to start the body into luminescence. When this critical temperature is below the red heat, the phosphorescent glow attracts attention, and investigation follows. When, however, the temperature of luminescence is high, the effect, however marked it may be, is masked by the ordinary incandescence to be expected at that temperature, and it is overlooked. Luminescence by heat is perforce transient. It is due to the expenditure of energy which has been stored by previous action. If we wish to see the effect repeated, we must restore to the material the potential energy which it has lost.

I am not in position to state positively that the glow of magnesium oxide is due to luminescent vibrations,

* Edward Weston: "Am. Institute of E. Engineers," vol. vi., p. 20.

* W. H. Pickering: "Proceedings of the American Academy of Arts and Sciences, vol. xv, p. 240.

† J. Thomsen: Journal fur praktische Chemie," N. F., 16, p. 97.

‡ Ernest Merritt: "American Journal of Science," vol. xxxvii., p. 167.

* Rosetti ("Beiblaetter zu den Annalen der Physik," 2, p. 333) gives as the temperature of the gas flame, 1 360°; of the positive carbon of the arc, at the hottest point, 3,900°; of the negative carbon, 2,450°.

† Becquerel, "Annales de Chimie et de Physique" (3), 55.

but I am of the opinion that such will be found to be the case. Other metallic oxides also show peculiarities of radiation which find their explanation most readily under that theory. While studying the distribution of energy in the visible spectrum of the lime light, three years ago, Mr. Franklin and I found that a freshly ignited cylinder under the oxy-hydrogen flame glowed with a brilliancy equal to that of the magnesium light itself.* This state of affairs lasted but a moment, however, and no amount of heating would bring out an old cylinder again into its initial splendor. It was plain that we were taking advantage of vibratory power stored in the lime at some stage in its preparation. These vibrations, disengaged by the blowpipe, gave out in a very short time, after which the performance of the lime degenerated rapidly to the level which corresponds to ordinary radiation at the temperature in question.

You are all acquainted with the beautiful greenish-yellow light which the oxide of zinc emits under the flame of the blowpipe. It is entirely different from the light of the incandescent charcoal on which it lies, although the two cannot differ widely in temperature. The zinc oxide is luminescent, the carbon is simply incandescent, in the usual sense of the word. This is a case which lends itself readily to study, since the temperature at which the abnormal glow appears is a comparatively moderate one. Last summer I took the matter up, with the efficient co-operation of Mr. B. W. Snow Instructor in Physics in Cornell University. We made a systematic comparison of the radiation from zinc oxide and from platinum, at temperatures between the redheat and 1,000° C., measuring temperatures and studying spectra by methods which I cannot dwell upon here. Since the results which we obtained are of a character to illustrate the points which seem to me most significant, in this question of the radiation of the metallic oxides, I will indicate them graphically.

Zinc oxide is a rather brilliant white pigment. Its radiating power, therefore, according to the theory of exchanges, should be very small. At temperatures below 700° C. we found it to be very much lower than that from platinum throughout the spectrum, and the light from the oxide to be of a duller red. Platinum is taken as the standard. The law according to which the visible radiation of platinum rises from zero at the extreme red heat, as the temperature rises, varies with the wave length. It had to be especially determined for the purposes of our investigation in each region of the spectrum to which our measurements were extended.

At about 700° a sudden change occurs in the character of the light from the oxide. It becomes brighter than the platinum of the same temperature, the increase showing itself principally at the ends of the spectrum. At 707° and 739° the emanations are selective to a marked degree, the yellow being relatively very weak. Measurements of fresh films of the oxide at still higher temperatures revealed the further development of the abnormal radiation of this substance. At 878° and 1,034° there is transition into a third and, apparently, a final stage. The red end of the spectrum loses its prominence, and the curve seems to be developing into a straight line, the trend of which is such as to indicate that zinc oxide, as we pass from the longer to the shorter wave lengths of its spectrum, increases in superiority over platinum at the same temperature.

It soon became evident, from the character of our results, that radiation at temperatures above about 800° were of a very evanescent sort, falling off in intensity and changing in quality from the first instant in which the oxide was heated. To follow these rapid changes proved a trying task. By taking a great many fresh films of the oxide and watching the time changes of one portion of the spectrum after another, however, we were able to obtain data which show the intensity of radiation and its character, relative again to that of platinum, after the oxide had been maintained at 1,013° for a period of 30 seconds, of 60 seconds, of 300 seconds, and of 600 seconds. At the end of the ten minutes, the changes, although not entirely completed, were very slow.

The evidence of the existence of luminescence afforded by these measurements seems to us to be nearly conclusive. Extension of the investigation to other of the metallic oxides and to wider ranges of temperature would, doubtless, lead to results more striking.

The application of all this to the problem of the light of the future is as follows: The fundamental question is that of efficiency. High efficiency at low temperatures means selected radiation, which appears to be a characteristic of luminescence and not of ordinary incandescence. The study of the radiation of the metallic oxides above the red heat reveals the existence of properties which lead us to regard them as being luminescent "by heat." It is from such bodies that radiation of high efficiency is to be looked for. We have in magnesium oxide a member of this particular class, and we have seen that when it is heated in the process of formation it gives us a light the efficiency of which is unapproached by that of other artificial illuminants.

The problem is easily stated. (1) We need a body which is rendered vividly luminescent by heat. The metallic oxides would seem to offer us many such. (2) The material is to be brought to the temperature at which its luminescence is most marked. Does it not seem probable that the best method, as in the case of carbon, will not be that of direct combustion, but of heating through the agency of the electric current? (3) The material must be restored from time to time. Whether rejuvenation is to be secured through electrical, chemical, actinic or mechanical means remains to be determined.

Luminescence "by heat" offers, however, only a partial solution of the problem of the highest efficiency. However great the efficiency of the luminescent itself, it is accompanied by incandescence of the ordinary kind. The ultimate solution is to be sought for along other lines. Incandescence is too expensive a means of exciting luminescence. There are many other ways in which it may be generated; friction, chemical action, the impact of light waves, electrical excitation, certain vital processes, are known to result in the production of light. The physics of these phenomena is, for the most part, undeveloped. I know of but two attempts to determine the efficacy of this "light without heat," as it has sometimes been called. The intensity is, as a rule, very small, and the heat has doubtless been regarded as quite below the range of even our most sensitive apparatus. One of these two cases is of especial interest to the electrician. It is that of the spark discharge in vacuo. Professor S. P. Langley and Mr. F. W. Very, in a recent remarkable paper, entitled "The Cheapest Form of Light," speak of the heat generated in the Geissler tube as so minute as to seem to defy direct investigation. It has, however, been successfully measured by Dr. Staub, of the University of Zurich, by means of one of the most delicate instruments for the measurement of heat—the Bunsen ice calorimeter.*

In Staub's experiments the vacuum tube was smoked with lampblack and inserted in the ice calorimeter. The ice melted in a given time afforded a measure of the total heat generated by the electric discharge through the tube. A repetition of the determination with the unsmoked tube, under which conditions the light-giving rays could escape, gave the energy of nonluminous radiation. The efficacy was found to be 3·268 per cent. The extremely small candle power of the light derived from the electric discharge in vacuo may seem to preclude all questions of its utilization in practical illumination. The result is one, however, which should not be lost sight of. It suggests a field of investigation which may prove unexpectedly fruitful.

The Geissler tube effect was not the source to which Langley and Very applied the term "the cheapest form of light." The subject of their research was the light of a Cuban fire-fly. Their work cannot fail to excite the highest admiration of every one who is able to appreciate the difficulties of such an investigation. The exploration of the heat spectrum of so insignificant a source of light is a task which very few physicists would, I think, have considered practicable, but it has been carried through by these investigators to complete success.

When we study the curve of distribution of energy in the spectrum of the fire-fly thus obtained, and compare it with the corresponding curves for gas light, the arc light, and sunlight, we find the expression, "the cheapest form of light," which is applied to the light of the fire-fly by Langley and Very, to be fully justified. All the energy of its spectrum is massed within the narrow limits of the visible spectrum, and what is more, by far the greater part of it is in the form of rays which are especially important for the purposes of radiation, the particular rays which give us yellow and green light. The non-luminous radiation which accompanies the light of the fire-fly seems to be so insignificant that it was with difficulty that it could be estimated, even with the almost inconceivably delicate apparatus used by Langley and Very. They give the efficiency as about 400 times as great as that of a gas flame. It cannot fall appreciably below 100 per cent.

In what I have said this evening, I fear that I have fallen far short of what might have been expected of a lecturer on the artificial light of the future. I have endeavored to show that the efficiency of our present methods is too low to meet the demands of the future for economical illumination, and that whether we ever succeed in approaching the perfect economy of nature's light-making processes, as exemplified in the fire-fly, or not, there are many sources of light which promise high efficiency. If I have succeeded in indicating, even vaguely, some of the conditions of the problem of the utilization of these, and in pointing out some of the lines of investigation which are to be followed in the development of new methods of lighting, my mission has been fulfilled.

* See the "American Journal of Science," vol. xxxviii., p. 100.

* G. Staub: Inaugural Dissertation, Zurich, 1890. (See the "Bieblaetter zu den Annalen der Physik," 14: p. 538.)

[Continued from SUPPLEMENT, No. 779, page 12449.]

THE ELECTROMAGNET.*

By Professor SILVANUS P. THOMPSON, D.Sc., B.A., M.I.E.E.

II.

TO-NIGHT we have to discuss the law of the magnetic circuit in its application to the electromagnet, and in particular to dwell upon some experimental results which have been obtained from time to time by different authorities as to the relation between the construction of the various parts of an electromagnet and the effect of that construction on its performance. We have to deal not only with the size, section, length, and material of the iron cores, and of the armatures of iron, but we have to deal also with the winding of the upper coil, and its form, and we have to speak in particular about the way in which the shaping of the core and of the armature affects the performance of the electromagnet in acting on its armature, whether in contact or at a distance. But before we enter on the last more difficult part of the subject, we will deal solely and exclusively with the law of force of the magnet upon its armature when the two are in contact with one another. In other words, with the law of traction.

I alluded in a historical manner in the last lecture to the principle of the magnetic circuit, telling you how the idea had gradually grown up, perforce, from a consideration of the facts. The law of the magnetic circuit was, however, first thrown into shape in 1873 by Professor Rowland, of Baltimore. He pointed out that if you consider any simple case, and find (as electricians do for the electric circuit) an expression for the magnetizing force which tends to drive the magnetism round the circuit, and divide that by the resistance to magnetization reckoned also all round the circuit, the total of those two gives you the total amount of flow or flux of magnetism. That is to say, one may calculate the quantity of magnetism that passes in that way round the magnetic circuit in exactly the same way as one calculates the strength of the electric current by the law of Ohm. Rowland, indeed, went a great deal further than this, for he applied this very calculation to the experiments made by Joule more than 30 years before, and from those experiments deduced the degree of magnetization to which Joule had driven the iron of his magnets, and by inference obtained the amount of current that he had been causing to circulate. Now this law requires to be written out in a form that can be used for future calculation. To put it in words without any symbols, we must first reckon out from the number of turns of wire in the coil, and the number of amperes of current which circulates in them, the whole *magnetomotive force*—the whole of that which tends to drive magnetism along the piece of iron—for it is, in fact, proportional to the strength of the current, and the number of times it circulates. Next we must ascertain the resistance which the magnetic circuit offers to the passage of the magnetic lines. I here avowedly use Joule's own expression, which was afterward adopted by Rowland, and, for short, so as to avoid having four words, we may simply call it the *magnetic resistance*.

Mr. Heaviside has suggested, as an advisable alternative term, magnetic *reluctance*, in order that we may not confuse the resistance to magnetism in the magnetic circuit with the resistance to the flow of current in an electric circuit. However, we need not quarrel about terms. Magnetic reluctance is sufficiently expressive. Then having found these two, the quotient of them gives us a number representing—I must not call it the strength of the magnetic current—I will call it simply the quantity or number of magnetic lines which flow round the circuit. Or, if we could adopt a term which is used on the Continent, we might call it simply *the magnetic flux*. The flux of magnetism being the analogue of the flow of electricity in the electric law. The law of the magnetic circuit may then be stated as follows:

$$\text{Magnetic flux} = \frac{\text{magneto-motive force}}{\text{reluctance}}$$

However, it is more convenient to deal with these matters in symbols, and therefore the symbols which I use, and have long been using, ought to be explained to you.

For the number of spirals in a winding I use the letter S. For the strength of current, or number of amperes, the letter i. For the length of a bar, or core, I am going to use the letter l, for the area of cross section the letter A, for the permeability of the iron which we discussed in the last lecture, the Greek symbol μ, and for the total magnetic flux, the number of magnetic lines, I use the letter **N**. Then our law becomes as follows:

$$\text{Magneto-motive force } \frac{4\pi\, Si}{10}.$$

$$\text{Magnetic reluctance } \Sigma \frac{l}{A\mu}$$

$$\text{Magnetic flux} \ldots\ldots \mathbf{N} = \frac{\dfrac{4\pi \cdot Si}{10}}{\Sigma \dfrac{l}{A\mu}}$$

If we take the number of spirals and multiply by the number of amperes of current, so as to get the whole amount of circulation of electric current expressed in so many ampere turns, and multiply by 4π, and divide by ten, in order to get the proper unit (that is to say, multiply it by 1·257), that gives us the magneto-motive force.

For magnetic reluctance, calculate out the reluctance exactly as you would the resistance of an electric conductor to the flow of electricity, or the resistance of a conductor of heat to the flow of heat. It will be proportionate to the length, inversely proportional to the cross section and inversely proportional to the conductivity, or, in the present case, to the magnetic permeability. Now if the circuit is a simple one, we may simply write down here the length, and divide it by the area of the cross section and the permeability, and so find the value of the reluctance. But if the circuit be not a simple one, if you have not a simple ring of iron of equal section all round, it is necessary to consider the circuit in pieces as you would an electric circuit, ascertaining separately the reluctance of the separate parts, and adding all together. As there may be a number of such terms to be added together, I have prefixed the expression for the magnetic reluctance by the sign Σ of summation. But it does not by any means follow, because we can write a thing down as simply as that, that the calculation out of it will be a very simple matter. In the case of magnetic lines we are quite unable to do as one does with electric currents to insulate the flow. An electric current can be confined (provided we do not put it in at 10,000 volts pressure, or anything much bigger than that) to a copper conductor by an adequate layer of adequately strong—and I use the word "strong" both in a mechanical and electrical sense—insulating material. There are materials whose conductivity for electricity as compared with copper may be regarded perhaps as millions of millions of millions of times less, that is to say, they are practically perfect insulators. There are no such things for magnetism.

The most highly insulating substance we know of for magnetism is certainly not 10,000 times less permeable to magnetism than the most highly magnetizable substance we know of, namely, iron in its best condition; and when one deals with electromagnets where curved portions of iron are surrounded with copper or with air, or other insulating material, one is dealing with substances whose permeability, instead of being infinitely small, compared with the iron is quite considerable. We have to deal mainly with iron when it has been well magnetized. Its permeability compared with air is from 1,000 to 100 roughly, that is to say, the permeability of air compared with the iron is not less than from one one-hundredth to one one-thousandth part. That means that it is quite possible to have a very considerable leakage of magnetic lines from iron into air occurring to complicate one's calculations, and prevent an accurate estimate being made of the true magnetic reluctance of any part of the circuit. Suppose, however, that we have got over all these difficulties, and made our calculations of the magnetic reluctance. Then dividing the magneto-motive force by the reluctance gives us the whole number of magnetic lines.

There, then, is in its elementary form the law of the magnetic circuit stated exactly as Ohm's law is stated for electric circuits. But, as a general rule, one requires this magnetic law for certain applications, in

* Lectures delivered before the Society of Arts, London, 1890. From the Journal of the Society.

which the problem is not to calculate from those two quantities what the total of magnetic lines will be. In most of the cases a rule is wanted for the purpose of calculating back. You want to know how to build a magnet so as to give you the requisite number of magnetic lines. You start by assuming that you need to have so many magnetic lines, and you require to know what magnetic reluctance there will be, and how much magneto-motive force will be needed. Well, that is a matter precisely analogous to those which every electrician comes across. He does not always want to use Ohm's law in the way in which it is commonly stated, to calculate the current from the electromotive force and the resistance; he often wants to calculate what is the electromotive force which will send a given current through a known resistance. And so do we. Our main consideration to-night will be devoted to the question, How many ampere-turns of copper wire winding must be provided in order to drive the required quantity of magnetism through any given magnetic reluctance? Therefore, we will state our law a little differently. What we want to calculate out is the number of ampere-turns required. When once we have got that, it is easy to say what the copper wire must consist of; what sort of wire, and how much of it. Turning, then, to our algebraic rule, we must transform it, so as to get all the other things, besides the ampere-turns, to the other side of the equation. So we write the formula:

$$S\,i = \frac{\mathbf{N} \cdot \Sigma \dfrac{l}{A\,\mu}}{1{\cdot}257}$$

We shall have, then, the ampere turns equal to the number of magnetic lines we are going to force round the circuit multiplied by the sum of the magnetic reluctances divided by 1·257. Now this number, 1·257, is the constant that comes in when the length, l, is expressed in centimeters, the area in square centimeters, and the permeability in the usual numbers. Many persons, unfortunately—I say so advisedly because of the waste of brain labor that they have been compelled to go through—prefer to work in inches and pounds and feet. They have, in fact, had to learn tables instead of acquiring them naturally without any learning. If the lengths be specified in inches, and areas in square inches, then the constant is a little different. The constant in that case, for inches and square inch measures, is 0·3133, so that the formula becomes:

$$S\,i = \mathbf{N} \times \Sigma \frac{l''}{A''\mu} \times 0{\cdot}3133$$

Here it is convenient to leave the law of the magnetic circuit, and come back to it from time to time as we require. What I want to point out before I go to any of the applications is that with the guidance provided by this law, one after another the various points that come under review can be arranged and explained, and that there does not now remain—if one applies this law with judgment—a single fact about electromagnets which is either anomalous or paradoxical. Paradoxical some things may seem in form, but they all reduce to what is perfectly rational when one has a guiding principle of this kind to tell you how much magnetization you will get under given circumstances, or to tell you how much magnetizing power you require in order to get a given quantity of magnetization. I am using the word "magnetization" there in the popular sense, not in the narrow mathematical sense in which it has sometimes been used (*i. e.*, for the magnetic moment per unit cube of the material). I am using it simply to express the fact that the iron or air, or whatever it may be, has been subjected to the process which results in there being magnetic lines of force induced through it.

Now let us apply this law of magnetic circuit in the first place to the traction, that is to say, the lifting power of electro-magnets. The law of traction I assumed in my last lecture, for I made it a basis of a method of measuring the amount of permeability. The law of magnetic traction was stated once for all by Maxwell, in his great treatise, and it is as follows:

$$P\,(\text{dynes}) = \frac{\mathbf{B}^2 A}{8\pi}$$

where A is the area in square centimeters. This becomes

$$P\,(\text{grammes}) = \frac{\mathbf{B}^2 A}{8\pi \times 981}$$

That is, the pull in grammes per square centimeter is equal to the square of the magnetic induction. $\mathbf{B}$ (being the number of magnetic lines to the square centimeter), divided by 8π, and divided also by 981. To bring grammes into pounds you divide by 453·6; so that the formula then becomes:

$$P\,(\text{lb.}) = \frac{\mathbf{B}^2 A}{11{,}183{,}000}$$

or if square inch measures are used:

$$P\,(\text{lb.}) = \frac{\mathbf{B}^2 A''}{72{,}134{,}000}$$

To save future trouble we will now calculate out from the law of traction the following table; in which the traction in grammes per square centimeter or in pounds per square inch is set down opposite the corresponding value of $\mathbf{B}$.

This simple statement of the law of traction assumes that the distribution of the magnetic lines is uniform all over the area we are considering; and that, unfortunately, is not always the case. When the distribution is not uniform, then the mean value of the squares becomes greater than the square of the mean value, and consequently the pull of the magnet at its end face may, under certain circumstances, become greater than the calculation would lead you to expect—greater than the average of $\mathbf{B}$ would lead you to suppose. If the distribution is not uniform over the area of contact, then the accurate expression for the tractive force (in dynes) will be

$$P = \frac{1}{8\pi}\int \mathbf{B}^2 dA$$

the integration being taken over the whole area of contact.

TABLE VI.—MAGNETIZATION AND MAGNETIC TRACTION.

$\mathbf{B}$ lines per sq. cm.	$\mathbf{B}''$ lines per sq. in.	Dynes per sq. centim.	Grammes per sq. centim.	Kilogrs. per sq. centim.	Pounds per sq inch
1,000	6,450	39,790	40·56	·0456	·577
2,000	12,900	159,100	162·3	·1623	2·308
3,000	19,350	358,100	365·1	·3651	5·190
4,000	25,800	636,600	648·9	·6489	9·228
5,000	32,250	994,700	1,014	1·014	14·39
6,000	38,700	1,432,000	1,460	1·460	20·75
7,000	45,150	1,950,000	1,987	1·987	28·26
8,000	51,600	2,547,000	2,596	2·596	36·95
9,000	58,050	3,223,000	3,286	3·286	46·72
10,000	64,500	3,979,000	4,056	4·056	57·68
11,000	70,950	4,815,000	4,907	4·907	69·77
12,000	77,400	5,730,000	5,841	5·841	83·07
13,000	83,850	6,725,000	6,855	6·855	97·47
14,000	90,300	7,800,000	7,550	7·550	113·1
15,000	96,750	8,953,000	9,124	9·124	129·7
16,000	103,200	10,170,000	10,390	10·39	147·7
17,000	109,650	11,500,000	11,720	11·72	166·6
18,000	116,100	12,890,000	13,140	13·14	186·8
19,000	122,550	14,360,000	14,630	14·63	208·1
20,000	129,000	15,920,000	16,230	16·23	230·8

This law of traction has been verified by experiment. The most conclusive investigations were made about 1886 by Mr. R. H. M. Bosanquet, of Oxford, whose apparatus is depicted in Fig. 22. He took two cores of

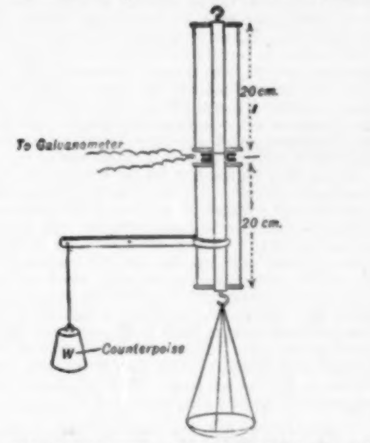


FIG. 22.—BOSANQUET'S VERIFICATION OF THE LAW OF TRACTION.

iron, well faced, and surrounded them both by magnetizing coils, fastened the upper one rigidly, and suspended the other one on a lever with a counterpoise weight. To the lower end of this core he hung a scale pan, and measured the traction of one upon the other when a known current was circulating a known number of times round the coil. At the same time he placed an exploring coil round the joint, that exploring coil being connected, in the manner with which we were experimenting last week, with a ballistic galvanometer, so that at the moment when the two surfaces parted company, or at the moment when the magnetization was released by reversing the magnetizing current, the galvanometer indication enabled you to say exactly how many magnetic lines went through that exploring coil. So that, knowing the area, you could calculate the number per square centimeter, and you could, therefore, compare $\mathbf{B}^2$ with the pull per square centimeter obtained directly on the scale pan. Bosanquet found that even when the surfaces were not absolutely perfectly faced the correspondence was very close indeed, not varying by more than one or two per cent., except with small magnetizing forces, say forces less than five units. When one knows how irregular the behavior of iron is when the magnetizing forces are so small as this, one is not astonished to find a lack of proportionality. The correspondence was, however, sufficiently exact to say that the experiments verified the law of traction, that the pull is proportional to the square of magnetic induction through the area, and integrated over that area.

Now, the law of traction being in that way established, one at once begins to get some light upon the subject of the design of electromagnets. Indeed, without going into any mathematics, Joule had foreseen this when he in some instinctive sort of way seemed to consider that the proper way to regard an electro-magnet for the purpose of traction was to think how many square inches of contact surface it had. He found that he could magnetize iron up until it pulled with a force of 175 lb. to the square inch, and he doubted whether a traction as great as 200 lb. per square inch could be obtained.

In the following table Joule's results (see Table I.) are recalculated, and the values of $\mathbf{B}$ deduced:

I will now return to the data in Table VI., and will ask you to compare the last column with the first. Here are the various values of $\mathbf{B}$, that is to say, the amounts of magnetization you get into the iron. You cannot conveniently crowd more than 20,000 magnetic lines to the square centimeter of the best iron, and, as a reference to the curves of magnetization shows, it is not expedient in the practical design of electromagnets to attempt, except in extraordinary cases, to crowd more than about 16,000 magnetic lines into the square centimeter. The simple reason is this, that if you are working up the magnetic force, say from 0 up to 50, a magnetizing force of 50 applied to good wrought iron will give you only 16,000 lines to the square centimeter, and the permeability by that time has fallen to about 320. If you try to force the magnetization any further, you find that you have to pay for it so greatly. If you want to force another 1,000 lines through the square centimeter, to go from 16,000 to 17,000, you have to add on an enormous magnetizing force; you have to double the whole force from that point to get another 1,000 lines added. Obviously it would be much better to take a larger piece of iron and not to magnetize it too highly—to take a piece a quarter as large again, and to magnetize that less forcibly. It does not therefore pay to go much above 16,000 lines to a square centimeter; that is to say, expressing it in terms of the law of traction, and the lb. per square inch, it does not pay to design your electromagnet so that it shall have to carry more than about 150 lb. to the square inch. This shall be our practical rule: let us at once take an example.

If you want to design an electromagnet to carry a load of one ton, divide the ton, or 2,240 lb., by 150, and that gives the requisite number of square inches of wrought iron, namely, 14·92, or say 15. Of course, one would work with a horseshoe-shaped magnet, or something equivalent—something with a return circuit—and calculate out the requisite cross section, so that the total area exposed might be sufficient to carry the given load at 150 lb. to the square inch. And as a horseshoe magnet has two poles, the cross section of the bar of which it is made must be 7½ square inches. If of round iron, it must be about 3⅛ inches in diameter; if of square iron, it must be 2¾ inches each way.

That settles the size of the iron, but not the length. Now the length of the iron, if only one considers the law of the magnetic circuit, ought to be as short as it can possibly be made. Reflect for what purpose we are designing. The design of an electromagnet is to be considered, as every design ought to be, with a view to the ultimate purpose to be served by that which you are designing. The present purpose is the actual sticking on of the magnet to a heavy weight, not acting on another magnet at a distance, not pulling at an armature separated from it by a thick layer of air; we are dealing with traction in contact. The question is—how long a piece of iron shall we need to bend over? The answer is—take length enough, and no more than enough, to permit of room for winding on the necessary quantity of wire to carry the current which will give the requisite magnetizing power. But this latter we do not yet know; it has to be calculated out by the law of the magnetic circuit. That is to say, we must calculate the magnetic flux and the magnetic reluctance as best we can; then from these calculate the ampere turns of current; and from this calculate the needful quantity of copper wire, so arriving finally at the proper length of the iron core. It is obvious, the cross section being given, and the value of $\mathbf{B}$ being prescribed, that settles the whole number of magnetic lines, $\mathbf{N}$, that will go through the section. It is self-evident that length adds to the magnetic resistance, and, therefore, the longer the length is, the greater have to be the number of ampere turns of circulation of the current; while the less the length is, the smaller need be the number of ampere turns of circulation. Therefore you should design the electromagnet as stumpy as possible, that is to say, make it a stumpy arch, even as Joule did when he came across the same problem, and arrived, by a sort of scientific instinct, at the right solution. You should have no greater length of iron than is necessary in order to get the windings on. Then you see you cannot absolutely calculate the length of the iron until we have an idea about the winding, and we must settle, therefore, provisionally about the windings. Take a simple ideal case. Suppose we had an indefinitely long, straight iron rod, and we wound that from end to end with a magnetizing coil. How thick a coil, how many ampere turns of circulation per inch length, will you require in order to magnetize up to any particular degree? It is a matter of very simple calculation. You can calculate exactly what the magnetic reluctance of an inch length of the core will be. For example, if you are going to magnetize up to 16,000 lines per square centimeter, the permeability will be 320. You can take the area anything you like, and consider the length of one inch; you can therefore calculate the magnetic reluctance per inch of conductor, and then you can at once say how many ampere turns per inch would be necessary in order to give the desired indication of 16,000 magnetic lines to the square centimeter. And knowing the properties of copper wire, and how it heats up when there is a current, and knowing also how much heat you can get rid of per square inch of surface, it is a very simple matter to calculate what minimum thickness of copper the fire insurance companies would allow you to use. They would not allow you to have too thin a copper wire, because if you provide an insufficient thickness of copper, you still must drive your amperes through it to get a sufficient number of ampere turns per inch of length; and if you drive those amperes through cop-

TABLE VII.—JOULE'S RESULTS RECALCULATED.

Description of Electromagnet		Section. sq. in.	Section. sq. cen.	Load. lbs.	Load. kilos.	lbs. per sq. in.	kilos. per sq. cm.	$\mathbf{B}$	Ratio of load to weight
Joule's own electromagnets	No. 1	10	64·5	2090	947	104·5	7·35	13,600	330
	No. 2	0·196	1·26	49	22	125	8·75	14,700	324
	No. 3	0·0436	0·28	12	5·4	137·5	9·75	15,410	1,286
	No. 4	0·0012	0·0077	0·202	·009	81	5·7	11,830	2,834
Nesbit's		4·5	29·1	1428	649	158·5	11·2	16,550	26
Henry's		3·94	25·3	750	340	95	6·7	12,800	36
Sturgeon's		0·196	1·26	53	22·6	267·3	18·95	14,850	149

per winding of an insufficient thickness the copper wire will overheat, and your insurance policy will be revoked. You therefore are compelled, by the practical consideration of not overheating, to provide a certain thickness of copper wire winding. I have made a rough calculation for certain cases, and I find that for such electromagnets as one may ordinarily deal with, it is not necessary in any case of practical work to use a copper wire winding the total thickness of which is greater than about half an inch; and, as a matter of fact, if you use as much as half an inch, you need not then wind the coil all along, for if you will use copper wire winding, no matter what the size, whether thin or thick, so that the total thickness of copper outside the iron is half an inch, you can, without overheating, using good wrought iron, make one inch of winding do for 20 inches length of iron. That is to say, you do not really want more than $\frac{1}{40}$ of an inch of thickness of copper outside the iron to magnetize up to the prescribed degree of saturation that indefinitely long piece of which we are thinking, without overheating the outside surface in such a way as to violate the insurance rules. Take it roughly, if you wind to a thickness of half an inch, the inch length of copper will magnetize 20 inches length of iron up to the point where $\mathbf{B}$ equals 16,000. If then we have a bar bent into a sort of horseshoe in order to make it stick on to a perfectly fitting armature, also of equal section and quality, we really do not want more than one inch along the inner curve for every 20 inches of iron. An extremely stumpy magnet, such as I have sketched in Fig. 23, will therefore do, if one can only get the iron

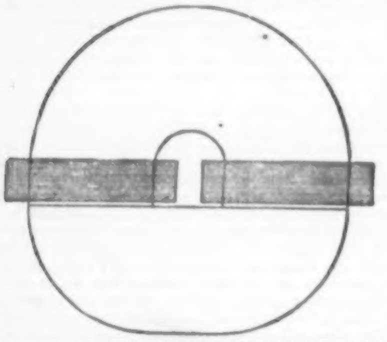


FIG. 23.—STUMPY ELECTROMAGNET.

sufficiently homogeneous throughout. If instead of crowding the wire near the polar parts, we could wind entirely all round the curved part, though the layer of copper winding would be half an inch thick inside the arch, it would be much less outside. Such a magnet, provided the armature fitted with perfect accuracy to the polar surfaces, and provided a battery were arranged to send the requisite number of amperes of current through the coils, would pull with a force of one ton, the iron being but 3½ inches in diameter. For my own part, in this case, I should prefer not to use round iron, one of square or rectangular section being more convenient; but the round iron would take less copper in winding, as each turn would be of minimum length if the section were circular.

Now, this sort of calculation requires to be greatly modified directly one begins to deal with any other case. A stumpy, short magnetic circuit with great cross section is clearly the right thing for the greatest traction. You will get the given magnetization and traction with the least amount of magnetizing force when you have the area as great as possible and the length as small as possible. You will kindly note that I have given you as yet no proofs for the practical rules that I have been using; they must come later. Also I have said nothing about the size of the wire, whether thick or thin. That does not in the least matter; for the ampere turns of magnetizing power can be made up in any desired way. Suppose we want on any magnet one hundred ampere turns of magnetizing power, and we choose to employ a thin wire that will only carry half an ampere, then we must wind 200 turns of that thin wire. Or, suppose we choose to wind it with a thick wire that will carry ten amperes, then we shall want only ten turns of that wire. The same weight of copper, heated up by the corresponding current to an equal degree of temperature, will have equal magnetizing power when wound on the same core. But the rules about winding the copper will be considered later.

Now if you look in the text books that have been written on magnetism for information about the so-called lifting power or portative force of magnets, you will find that from the time of Bernouilli downward, the law of portative force has claimed the attention of experimenters, who one after another have tried to give the law of portative force in terms of the weight of the magnets; usually dealing with permanent magnets, not electromagnets. Bernouilli gave a rule something of the following kind, which is commonly known as Häcker's rule:

$$\mathrm{P} = a\sqrt[3]{\mathrm{W}^2}$$

where W is the weight of the magnet, P the greatest load it will sustain, and a a constant depending on the units of weight chosen, on the quality of the steel and on its goodness of magnetization. If the weights are in pounds then a is found, for the best steels, to vary from 18 to 24 in magnets of horseshoe shape. This expression is equivalent to saying that the power which a magnet can exert—he was dealing with steel magnets; there were no electromagnets in Bernouilli's time—is equal to some constant multiplied by the three-halfth root of the weight of the magnet itself. The rule is accurate only if you are dealing with a number of magnets all of the same geometrical form, all horseshoes let us say, of the same general shape, made from the same sort of steel, similarly magnetized. In former years I pondered much on Häcker's rule, wondering how on earth the three-halfth root of the weight could have anything to do with the magnetic pull; and having cudgeled my brains for a considerable time, I saw that there was really a very simple meaning in it. What I arrived at was this: If you are dealing with a given material, say hard steel, the weight is proportional to the volume, and the cube root of the volume is something proportional to the length, and the square of the cube root forms something proportional to the square of the length, that is to say, to something of the nature of a surface. What surface? Of course the polar surface. This complex rule, when thus analyzed, turns out to be merely a mathematician's expression of the fact that the pull for a given material magnetized in a given way is proportional to the area of the polar surface; a law which in its simple form Joule seems to have arrived at naturally, and which in this extraordinarily academic form was arrived at by comparing the weights of magnets with the weight which they would lift. You will find it stated in many books that a good magnet will lift twenty times its own weight. There never was a more fallacious rule written. It is perfectly true that a good steel horseshoe magnet weighing 1 lb. ought to be able to pull with a pull of 20 lb. on a properly shaped armature. But it does not follow that a magnet which weighs 2 lb. will be able to pull with a force of 40 lb. It ought not to, because a magnet that weighs 2 lb. has not poles twice as big if it is the same shape. In order to have poles twice as big you must remember that three-halfth root coming in. If you take a magnet that weighs eight times as much, it will have twice the linear dimensions and four times the surface; and with four times the surface in a magnet of the same form, similarly magnetized, you will have four times the pull. With a magnet eight times as big you will have only four times the pull. The pull, when other things are equal, goes by surface, and not by weight, and therefore it is ridiculous to give a rule saying how many times its own weight a magnet will pull. It is also narrated as a very extraordinary thing that Sir Issac Newton had a magnet, a loadstone, which he wore in a signet ring, which would lift 234 times its own weight. I have had an electromagnet which would lift 2,500 times its own weight, but then it was a very small one, and did not weigh more than a grain and a half. When you come to small things, of course the surface is large proportionally to the weight. The smaller you go, the larger becomes that disproportion. This all shows that the old law of traction in that form was practically valueless, and did not guide you to anything at all, whereas the law of traction as stated by Maxwell, and explained further by the law of the magnetic circuit, proves a most useful rule.

From this digression let us return to the law of the magnetic circuit. I gave you in my first lecture, when speaking of permeability, the following rule for calculating the magnetic permeability. $\mathbf{B}$ was found in the following way: Take the pull in pounds, and the area of cross section in square inches, divide one by the other, and take the square root of the quotient; then multiplying by 1,317 gives B; or multiplied by 8,494 gives $\mathbf{B}$,. We have, therefore, a means of stepping from the pull per square inch to $\mathbf{B}$,, or from $\mathbf{B}$, to the pull per square inch. Now the other rule of the magnetic circuit also enables us to get from the ampere turns down to $\mathbf{B}$,, for on page 12463 we have the following expression for the ampere turns:

$$S\,i = \mathbf{N} \times \Sigma \frac{l''}{A''\mu} \times 0{\cdot}3133$$

and $\mathbf{N}$, the whole number of magnetic lines in the magnetic circuit, is equal to $\mathbf{B}$, multiplied by A'', or

$$\mathbf{N} = \mathbf{B}\,A''$$

From these we can deduce a simple direct expression, provided we assume the quality of iron as before, and also assume that there is no magnetic leakage, and that the area of cross section is the same all around the circuit, in the armature as well as in the magnet core. So that l'' is simply the mean total path of the magnetic lines around the closed magnetic circuit. We may then write

$$S\,i = \frac{\mathbf{B}\,l''}{\mu} \times 0{\cdot}3133$$

whence

$$\mathbf{B} = \frac{\mu \times S\,i}{l'' \times 0{\cdot}3133}$$

But by the law of traction, as stated above,

$$\mathbf{B} = 8494\sqrt{\frac{\mathrm{P\ (lbs.)}}{\mathrm{A\ (sq.\ in.)}}}$$

Equating together these two values of $\mathbf{B}$,, and solving, we get for the requisite number of ampere turns of circulation of exciting currents:

$$S\,i = 2661 \times \frac{l''}{\mu} \times \sqrt{\frac{\mathrm{P\ (lbs.)}}{\mathrm{A\ (sq.\ in.)}}}$$

This, put into words, amounts to the following rule for calculating the amount of exciting power that is required for an electromagnet pulling at its armature, in the case where there is a closed magnetic circuit with no leakage of magnetic lines. Take the square root of the pounds per square inch; multiply this by the mean total length (in inches) all round the iron circuit; divide by the permeability (which must be calculated from the pounds per square inch by help of Table VI. and Table II.); and finally multiply by 2,661; the number so obtained will be the number of ampere turns. One goes then at once from the pull per square inch to the number of ampere turns required to produce that pull in a magnet of given length and of the prescribed quality. In the case where the pull is specified in kilogrammes, the area of section in square centimeters, and the length in centimeters, the formula becomes

$$S\,i = 3951 \cdot \frac{l}{\mu}\sqrt{\frac{\mathrm{P}}{\mathrm{A}}}$$

As an example, take a magnet core of round annealed wrought iron, half an inch in diameter, 8 inches, bent to horseshoe shape. As an armature, another piece, 4 inches long, bent to meet the former. Let us agree to magnetize the iron up to the pitch of pulling with 112 lb. to the square inch. Reference to Table VI. shows that $\mathbf{B}$, will be about 90,000, and Table II. shows that in that case μ will be about 907. From these data calculate what load the magnet will carry, and how many ampere turns of circulation of current will be needed.

Ans.—Load (on two poles) = 43·97 lb.
Ampere turns needed = 372·5

N. B.—In this calculation it is assumed that the contact surface between armature and magnet is perfect. It never is; the joint offers additional resistance to the magnetic lines, and there will be some leakage. It will be shown later how to estimate these effects, and to allow for them in the calculations.

(To be continued.)

MEDICO-GYMNASTICS.

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THE effects of bodily exercise upon the functions of the abdominal organs in health called quite early the attention of the medical profession to the probability of arriving at some beneficial results by treating them by movements and manipulations when in diseased condition. But it seems as if the importance of medico-gymnastics in diseases of the alimentary canal has not been fully appreciated, while massage of the abdomen has become a fad, which threatens more and more to become an intolerable nuisance, for great stress is laid upon this means in a number of diseases where it still remains for the conscientious observer to notice a single case of severe character or long duration which has been carried through to a permanent cure. The prevailing practice, for instance, of prescribing "rubbing" as an excellent means against constipation with slow or deficient peristalsis seems so doubtful, to say the least, that there is danger that this practice alone will tend to degrade massage, a therapeutic agent of greatest value when judiciously employed, to the level of those much bragged of panaceas fit for hardly anything more than to bring money into the pockets of the "patentee." It is evident that the largest part of the alimentary canal, being easily accessible to the manipulations of the masseur, must be influenced accordingly. But the question naturally arises whether or not this influence always is for the better, and, if this question be answered in the affirmative, whether it is strong enough to carry the case through to a permanent cure or necessarily must stop at temporary relief only.

We know and understand easily the value of massage in removing persistent fecal occlusions in the bowels, especially at the cæcum and the sigmoid flexure, even when other means have failed to bring about an evacuation; but removing a lump of fæces is a purely mechanical procedure employed against a symptom only, not against the disease itself, whether this consists of atony of the muscular coats, or in a decreased secretion, or in something else, whatever it may be. Some men, with well known names as practical masseurs, claim that massage not only pushes the intestinal contents forward toward the rectum and increases the secretion of the parts manipulated, but that it also stimulates the bowels to more active peristaltic movement. For instance, Graham says:* "Massage improves the circulation, and pushes along the contents of the accessible portions of the stomach and intestines at the same time, *besides directly stimulating the muscular fibers to contraction;* . . ." with this expression plainly having in mind a peristaltic contraction. To Reibmayr the case seems so clear that it needs no proof beyond the well known fact of more regular evacuations for the time being, and his somewhat nonchalant assertion that "Die peristaltische Bewegung der Darme wird eine regere."†

A priori we may expect the intestinal musculature to contract under massage just as any other muscle under a mechanical stimulus, which expectation is also proved to be beyond doubt; but the experiments of Nothnagel‡ show us plainly that the contracting effect is exclusively local and cannot be compared with proper peristaltic contractions. And, even if such were the case, it is unreasonable to expect too much of this "exercise" of the involuntary muscles, and to maintain that they thereby regain such vigor as afterward, spontaneously, to perform their work without the normal stimulus of a strong "Bauchpresse," which is just the thing lacking in most cases of constipation, the abdominal walls being weakened by sedentary habits, pregnancy, etc., while the superficial respiration, natural in cases of long standing, at least, makes the movements of the diaphragm much less extensive. And no one claims, I suppose, to be able to increase the respiratory power or to strengthen the abdominal voluntary muscles to any extent by only "Bausch-massage." For this purpose exercise—movement—is necessary. But exercise is often prescribed without any advice whatsoever being given as to the kind of exercise most suitable for the individual case, and when the question is raised as to the kinds of exercise, walking and horseback riding are the only ones taken into consideration. Horseback riding will prove ample in most cases, I think, but for many it is too severe and cannot be endured; while in regard to walking—*i. e.*, the common, everyday, go-easy walking—the direct effect is comparatively small, though it, of course, is of great value as strengthening the whole system.

When in the following lines recommending a few movements used by medico-gymnasts to the consideration of the practitioner, it is perhaps not out of the way to emphasize that not one of them must be even thought of as a specific, but combined in a certain way they are intended to remove the causes of obstruction, if any there be, to stimulate the respiration, to improve the circulation in general, but especially in the vena-porta system, and to create a strong and healthy "Bauchpresse." The combination of the movements depends, as well as the movements themselves, on the particular needs of the case at hand, and can, of course, not be even touched upon in a short article, so that the programme below is not to be followed as a prescription, but only looked upon as an example to elucidate the general mode of procedure in this method of treating constipation.

1. In Fig. 1 the patient is represented as kneeling on a bench, his pelvis fixed by the support of the gymnast's knee on his sacrum, his arms stretched upward

* A Practical Treatise on Massage, etc., p. 104. New York: Wm. Wood & Co. 1884.

† Die Massage und ihre Verwerthung, etc., p. 53. Leipzig und Wien, 1886.

‡ Beitrage zur Physiologie und Pathologie des Darmes. Berlin, 1884.

and grasped by the gymnast around the wrists, thus by the traction on the pectorals and the expansion of the chest gaining a second support for the abdominal muscles, the two ends of which now are tolerably firm. If the gymnast now execute a slow, steady traction backward, regulating his strength according to that of the patient, who resists as much as he comfortably can do without interfering with the respiration, when he

FIG. 1.

comes to the position denoted in Fig. 2 it is plain that he thereby brings the abdominal muscles into play, not only exercising them, but also by their pressing on the intestines causing them to do part of the work done by his hand in massage, and finally accelerating the circulation in the abdominal tract. The operator brings the patient back to his original position and repeats the movement three to six times with a moment's intermission.

If there be very strong relaxation of the abdominal

FIG. 2.

muscles, it will be found more effective to reverse the movement, so that the patient bends backward to the arching position of Fig. 2, and from there rises to the erect position of Fig. 1, under resistance from the gymnast.

2. In Fig. 3 the patient stands between two poles, or in a doorway, with the upper arms horizontally sideward, the forearms and hands stretched upward, resting on the poles. The gymnast stands in front with his hands between the scapulæ. While the patient

FIG. 3.

rises to tiptoes at the moment of inspiration, the gymnast pulls the thoracic walls slightly forward, letting the hands slide along the ribs and executing quick vibrations till the position at the end of the inspiration is as in Fig. 4. During the exhalation the patient sinks down on his heels, while the gymnast relaxes his hold, and brings the hands back to their original place. Repeated five to fifteen times, this movement is intended to intensify the respiration, and by so doing not only to increase the movements of the diaphragm but also to decrease the blood pressure in the extra-pulmonary parts of the thoracic cavity,* whereby the venous blood of the abdomen—where the circulation is sluggish—will be, so to say, sucked up toward the heart, relieving the passive stasis of that part. The effect of the vibration is not satisfactorily explained, but it has been empirically noticed to be a valuable help in stimu-

FIG. 4.

lating the respiration. In a movement of this kind attention should be paid to the necessity of making the respiration powerful and deep, *without special effort, resembling dyspnœic respiration*, which never fails to exhaust the patient.

3. Fig. 5 represents sacral percussion. The patient, standing with support for the arms against the wall, and the feet a little parted, leans forward, so that the musculature of the abdominal region will be somewhat tense. The gymnast, with one hand supporting the

FIG. 5.

abdomen, executes with his clenched fist quick knocking or percussion over the sacrum during a couple of minutes, with the idea of thereby stimulating the nervous centers supplying the pelvic viscera in general, and more specially acting upon the rectum and the bladder by means of the sacral and pelvic plexuses. This manipulation is by many looked upon as invaluable in severe cases of piles.

The part of the programme now gone through consists of one strong active movement, one very much milder, and one manipulation, and I generally form a programme from such groups of two or three movements, which I have follow each other without any pause, but after which I insist upon at least five minutes' rest, either on the sofa or for stronger patients in walking.

As a second group the following three might be used:

4. The patient lies on the bench, and while his legs are fixed by the gymnast as in Fig. 6, he tries to elevate the body to a sitting position, or rather to an angle of

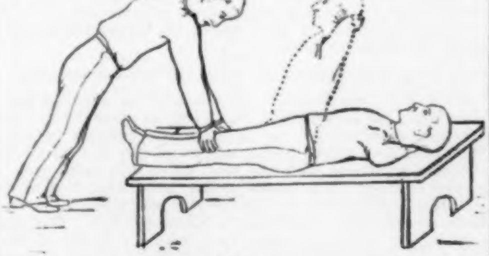


FIG. 6.

about sixty degrees, from which he again slowly returns to his first position, repeating this three to six times. The lower extremities being fixed as before said, and the thoracic walls by the effort, the abdominal muscles will be called to strong action, more especially perhaps the recti. A moderation of the work performed may, of course, easily be effected by moving the center of gravity toward or from the point of attachment of the active force, for instance by letting the patient rest his hands successively on the hips, behind the neck, or keeping them stretched upward in the axis of the trunk.

5. As the second part of this group may very well be applied the "Bauchmassage" proper, for which the patient takes a position in which the muscles are thoroughly relaxed, as in Fig. 7. The procedure of abdominal massage being dwelt upon at length in all handbooks on massage, there is no reason to take time and space for a description here; but it ought perhaps to be remarked that the way of kneading the colon, as generally recommended in manuals, viz., commencing at the cæcum and following the ascending,

FIG. 7.

transverse, and descending parts successively, must certainly not be used in cases of long standing where there are considerable accumulations of hard fecal matters with more or less dilatation. More can be gained by commencing the manipulation as far down in the left iliac fossa as possible, and slowly passing upward to the cæcum. It is evident that the usual way, if employed in these cases, only tends to make things worse, while this latter way offers opportunity to press the hardened substances forward in their natural course.

6. Fig. 8 shows the patient sitting in a comfortable position, totally passive, and the gymnast circumducting the thighs alternately outward and inward in large circles six to eight times, which is repeated in each

FIG. 8.

direction two to five times. If very large circles are used we may expect the movement to have some direct effect on the abdomen on account of the pressure effected at each upward turn, but it is mostly intended to improve the circulation of the lower extremities. The large veins being attached to the fascia, every movement of the hip joint will alternately increase and decrease the lumen of these vessels, acting consequently as a suction pump,* which of course will be of value for people of sedentary habits with their generally sluggish peripheral circulation.

Here comes in another period of rest.

7. The patient kneels on the bench. The gymnast, standing behind, takes hold under the armpits and allows the patient to fall forward to some extent while giving a pressing support to the patient's pelvis with

FIG. 9

his knee on the sacrum, and executes thereafter an oscillating movement of the trunk by making alternating sudden tractions on his shoulders. The movement, which, though in itself passive, is very tiresome on account of the position, cannot be repeated more than a few times, and must be carefully executed, especially

* Hartelius: Larobok i sjukgymnastik, p. 205. Stockholm, 1883.

* Loven. "Blode toch dera Kretslopp," cited by Hartelius, op. cit., p. 207.

in females. It must never be used in cases of hernia, prolapsus uteri, or uterine displacement.

8. After this a respiratory movement is to be recommended in order to regulate the circulation, which perhaps has suffered by the preceding, and "arm circumduction under toe heaving" seems to be suitable. The gymnast standing behind the patient makes the circumduction forward, upward, outward, downward, trying to bring the arms as far back as possible in

FIG. 16.

sinking. The patient rises on tiptoes when the arms are brought forward and upward, and sinks down again when the arms are brought back. Care must be taken to do the movement according to the natural rhythm of respiration, *i. e.*, the arms to be elevated during the inhalation, and *vice versa*.

These movements, or substitutes for them, for the execution of which about forty-five minutes to an hour are required, will be enough in the majority of cases.

For very strong persons several groups may be added, containing different forms of trunk bending, twistings, and circumductions as active movements, and a great variety of passive movements and manipulations. But we must always bear in mind the golden rule, rather do too little than too much, as nothing is gained by exhausting the patient.

When piles have their origin in constipation they disappear with the cause, and the means employed for the relief of the constipation is, therefore, indirectly, also in piles. When hemorrhoids are the result of pregnancy or tumors in the pelvis, they probably very seldom, if ever, come under the hands of the masseur or medico-gymnast. But when the source is found in pulmonary or cardiac diseases they must, of course, not be overlooked as a symptom of the deranged circulation, and must be healed accordingly. The stagnation in the abdomen must then be relieved by movements (both active and passive as far as the general condition will allow) and massage of the lower extremities, which then also tend to relieve another symptom in these cases—the cold feet. Respiratory movements of many forms are of great value as improving the general circulation, while local massage, consisting mostly of strokings and pressings on and about the piles, are recommended by many, *e. g.*, Hartelius* and Nebel.†

Most gratifying results are often obtained in cases of prolapsus ani, and I have found the prescription of Brandt to be an excellent one. He gives the patient first the sacrum percussion, already described in connection with constipation, after which he uses his "lifting of the S. romanum," which he describes as follows:‡

"The position of the patient is the common 'crook-half-lying' (see Fig. 7). The gymnast places himself on the right side of the patient. With his left hand over the shoulder and under the axilla of the patient, he tries, with his right hand on the abdominal wall over the patient's left groin, easily and carefully to push them downward and inward toward the inner side of the os ilium and there with a fine vibration to come under the first curvature of the S. romanum. The movement is then executed toward the back of the patient and toward the gymnast's own left hand. If correctly executed, the patient will plainly notice a pulling in sensation of the rectum. The movement is repeated three to four times."

In addition to these movements of a more local importance, the programme should contain such as will have a strengthening effect on the musculature of the whole lower part, especially the levator ani, besides movements of a more general character.

From what is said above about constipation, it is evident that the treatment recommended for this trouble also must be of value in dilatation of the bowels, as the whole treatment, as laid down above, is based upon efforts to cause the involuntary muscles to contract.—*Medical Record.*

* Op. cit., p. 277.

† "Bewegungskuren mittelst schwedischer Heilgymnastik und Massage," p. 260. Wiesbaden, 1889.

‡ "Gymnastiken ssom bote medel mot qvinliga underlifssjukdomar," p. 130. Stockholm, 1884.

DR. KOCH ON TUBERCULOSIS.

A SUPPLEMENT to the *British Medical Journal* contains "A Further Communication on a Remedy for Tuberculosis," translated from the original article published in the *Deutsche Medizinische Wochenschrift*, November 14, by Prof. Dr. Robert Koch, Berlin, as follows:

INTRODUCTION.

In an address delivered before the International Medical Congress I mentioned a remedy which conferred on the animals experimented on an immunity against inoculation with the tubercle bacillus, and which arrests tuberculous disease. Investigations have now been carried out on human patients, and these form the subject of the following observations.

It was originally my intention to complete the research, and especially to gain sufficient experience regarding the application of the remedy in practice and its production on a large scale, before publishing anything on the subject. But in spite of all precautions too many accounts have reached the public, and that in an exaggerated and distorted form, so that it seems imperative, in order to prevent all false impressions, to give at once a review of the position of the subject at the present stage of the inquiry. It is true that this review can, under these circumstances, be only brief, and must leave open many important questions.

The investigations have been carried on under my direction by Dr. A. Libbertz and Stabsarzt Dr. E. Pfuhl, and are still in progress. Patients were placed at my disposal by Prof. Brieger from his poliklinik, Dr. W. Levy from his private surgical clinic, Geheimrath Dr. Frantzel and Oberstabsarzt Kohler from the Charité Hospital, and Geheimrath v. Bergmann from the Surgical Clinic of the University.*

NATURE AND PHYSICAL CHARACTERS OF THE REMEDY.

As regards the origin and the preparation of the remedy I am unable to make any statement, as my research is not yet concluded: I reserve this for a future communication.† The remedy is a brownish transparent liquid, which does not require special care to prevent decomposition. For use, this fluid must be more or less diluted, and the dilutions are liable to decomposition if prepared with distilled water; bacterial growths soon develop in them, they become turbid, and are then unfit for use. To prevent this the diluted liquid must be sterilized by heat and preserved under a cotton wool stopper, or more conveniently prepared with a one-half per cent. solution of phenol.

MANNER OF USING THE REMEDY.

It would seem, however, that the effect is weakened both by frequent heating and by mixture with phenol solution, and I have therefore always made use of freshly prepared solutions. Introduced into the stomach the remedy has no effect; in order to obtain a trustworthy effect, it must be injected subcutaneously. For this purpose we have used exclusively the small syringe suggested by me for bacteriological work; it is furnished with a small India rubber ball and has no piston. This syringe can easily be kept aseptic by absolute alcohol, and to this we attribute the fact that not a single abscess has been observed in the course of more than a thousand subcutaneous injections. The place chosen for the injection—after several trials of other places—was the skin of the back between the shoulder blades and the lumbar region, because here the injection led to the least local reaction—generally none at all—and was almost painless.

EFFECT OF INJECTIONS IN HEALTHY INDIVIDUALS.

As regards the effect of the remedy on the human patient, it was clear from the beginning of the research that in one very important point the human being reacts to the remedy differently from the animal generally used in experiments—the guinea pig; a new proof for the experimenter of the all-important law that experiment on animals is not conclusive for the human being, for the human patient proved extraordinarily more sensitive than the guinea pig as regards the effect of the remedy. A healthy guinea pig will bear two cubic centimeters and even more of the liquid injected subcutaneously without being sensibly affected. But in the case of a full grown healthy man 0·25 cubic centimeter suffices to produce an intense effect. Calculated by body weight, the 1,500th part of the quantity which has no appreciable effect on the guinea pig acts powerfully on the human being. The symptoms arising from an injection of 0·25 cubic centimeter I have observed after an injection made in my own upper arm. They were briefly as follows: Three to four hours after the injection there came on pains in the limbs, fatigue, inclination to cough, difficulty in breathing, which speedily increased. In the fifth hour an unusually violent attack of ague followed, which lasted almost an hour. At the same time there was sickness, vomiting, and rise of body temperature up to 39·6° C. After twelve hours all these symptoms abated. The temperature fell, until next day it was normal, and a feeling of fatigue and pain in the limbs continued for a few days, and for exactly the same period of time the site of injection remained slightly painful and red. The lowest limit of the effect of the remedy for a healthy human being is about 0·01 cubic centimeter (equal to 1 cubic centimeter of the hundredth solution), as has been proved by numerous experiments. When this dose was used, reaction in most people showed itself only by slight pains in the limbs and transient fatigue. A few showed a slight rise of temperature up to about 38° C. Although the dosage of the remedy shows a great difference between animals and human beings—calculated by body weight—in some other qualities there is much similarity between them. The most important of these qualities is the specific action of the remedy on tuberculous processes of whatever kind.

THE SPECIFIC ACTION ON TUBERCULOUS PROCESSES.

I will not here describe this action as regards animals used for experiment, but I will at once turn to its extraordinary action on tuberculous human beings. The healthy human being reacts either not at all or scarcely at all—as we have seen when 0·01 cubic centimeter is used. The same holds good with regard to patients suffering from diseases other than tuberculosis, as repeated experiments have proved. But the case is very different when the disease is tuberculosis; the same dose of 0·01 cubic centimeter injected subcutaneously into the tuberculous patient caused a severe general reaction, as well as a local one. (I gave children, aged from 2 to 5 years, one-tenth of this dose—that is to say, 0·001 cubic centimeter; very delicate children, only 0·0005 cubic centimeter, and obtained a powerful but in no way dangerous reaction.) The general reaction consists in an attack of fever, which generally begins with rigors, raises the temperature above 39°, often up to 40°, and even 41° C.; this is accompanied by pain in the limbs, coughing, great fatigue, often sickness and vomiting. In several cases a slight icteric discoloration was observed, and occasionally an eruption like measles on the chest and neck. The attack usually begins four or five hours after the injection, and lasts from twelve to fifteen hours. Occasionally it begins later, and then runs its course with less intensity. The patients are very little affected by the attack, and as soon as it is over feel comparatively well, generally better than before it. The local reaction can be best observed in cases where the tuberculous affection is visible; for instance, in cases of lupus—here changes take place which show the specific antituberculous action of the remedy to a most surprising degree. A few hours after an injection into the skin of the back—that is, in a spot far removed from the diseased spots on the face, etc.—the lupus spots begin to swell and to redden, and this they generally do before the initial rigor. During the fever, swelling and redness increased, and may finally reach a higher degree, so that the lupus tissue becomes brownish and necrotic in places. Where the lupus was sharply defined we sometimes found a much swollen and brownish spot surrounded by a whitish edge almost a centimeter wide, which again was surrounded by a broad band of bright red.

* Dr. Koch here expressed his thanks to these gentlemen.

† Doctors wishing to make investigations with the remedy at present can obtain it from Dr. A. Libbertz, Lueneburger Strasse 28, Berlin, N. W., who has undertaken the preparation of the remedy, with my own and Dr. Pfuhl's co-operation. But I must remark that the quantity prepared at present is but small, and that larger quantities will not be obtainable for some weeks.

After the subsidence of the fever the swelling of the lupus tissue decreases gradually, and disappears in about two or three days. The lupus spots themselves are then covered by a crust of serum, which filters outward, and dries in the air; they change to crusts, which fall off after two or three weeks, and which, sometimes after one injection only, leave a clean red cicatrix behind. Generally, however, several injections are required for the complete removal of the lupus tissue. But of this more later on. I must mention, as a point of special importance, that the changes described are exactly confined to the parts of the skin affected with lupus. Even the smallest nodules, and those most deeply hidden in the lupus tissue, go through the process, and become visible in consequence of the swelling and change of color, while the tissue itself, in which the lupus changes have entirely ceased, remains unchanged. The observation of a lupus case treated by the remedy is so instructive, and is necessarily so convincing, that those who wish to make a trial of the remedy should, if at all possible, begin with a case of lupus.

THE LOCAL AND GENERAL REACTION TO THE REMEDY.

The specific action of the remedy in these cases is less striking, but is perceptible to eye and touch, as are the local reactions in cases of tuberculosis of the glands, bones, joints, etc. In these cases swellings, increased sensibility, and redness of the superficial parts are observed. The reaction of the internal organs, especially of the lungs, is not at once apparent, unless the increased cough and expectoration of consumptive patients after the first injection be considered as pointing to a local reaction. In these cases the general reaction is dominant; nevertheless, we are justified in assuming that here, too, changes take place similar to those seen in lupus cases.

THE DIAGNOSTIC VALUE OF THE METHOD.

The symptoms of reaction above described occurred without exception in all cases where a tuberculous process was present in the organism, after a dose of 0·01 cubic centimeter, and I think I am justified in saying that the remedy will, therefore, in future, form an indispensable aid to diagnosis. By its aid we shall be able to diagnose doubtful cases of phthisis; for instance, cases in which it impossible to obtain certainty as to the nature of the disease by the discovery of bacilli, or elastic fibers, in the sputum, or by physical examination. Affections of the glands, latent tuberculosis of bone, doubtful cases of tuberculosis of the skin, and such like cases, will be easily and with certainty recognized. In cases of tuberculosis of the lungs or joints which have become apparently cured, we shall be able to make sure whether the disease has really finished its course, and whether there be not still some disease spots from which it might again arise as a flame from a spark hidden by ashes.

THE CURATIVE EFFECT OF THE REMEDY.

Of much greater importance, however, than its diagnostic use is the therapeutic effect of the remedy. In the description of the changes which a subcutaneous injection of the remedy produces in portions of skin changed by lupus I mentioned that after the subsidence of the swelling and decrease of redness the lupus tissue does not return to its original condition, but that it is destroyed to a greater or less extent, and disappears. Observation shows that in some parts this result is brought about by the diseased tissue becoming necrotic, even after one sufficient injection, and, at a later stage, it is thrown off as a dead mass. In other parts, a disappearance or, as it were, a melting of the tissues seems to occur, and in such case the injection must be repeated to complete the cure.

ITS ACTION ON TUBERCULOUS TISSUE.

In what way this process occurs cannot as yet be said with certainty, as the necessary histological investigations are not complete. But so much is certain, that there is no question of a destruction of the tubercle bacilli in the tissues, but only that the tissue inclosing the tubercle bacilli is affected by the remedy. Beyond this, there is, as is shown by the visible swelling and redness, considerable disturbance of the circulation, and, evidently in connection therewith, deeply seated changes in its nutrition, which cause the tissue to die off more or less quickly and deeply, according to the extent of the action of the remedy.

To recapitulate, the remedy does not kill the tubercle bacilli, but the tuberculous tissue; and this gives us clearly and definitely the limit that bounds the action of the remedy. It can only influence living tuberculous tissue; it has no effect on dead tissue, as, for instance, necrotic cheesy masses, necrotic bones, etc., nor has it any effect on tissue made necrotic by the remedy itself. In such masses of dead tissue living tubercle bacilli may possibly still be present, and are

either thrown off with the necrosed tissue or may possibly enter the neighboring still living tissue under certain circumstances. If the therapeutic activity of the remedy is to be rendered as fruitful as possible, this peculiarity in its mode of action must be carefully observed. In the first instance, the living tuberculous tissue must be caused to undergo necrosis, and then everything must be done to remove the dead tissue as soon as possible, as, for instance, by surgical interference. Where this is not possible, and the organism can only help itself in throwing off the tissue slowly, the endangered living tissue must be protected from fresh incursions of the parasites by continuous application of the remedy.

THE DOSE.

The fact that the remedy makes tuberculous tissue necrotic, and acts only on living tissue, helps to explain another peculiar characteristic thereof—namely, that it can be given in rapidly increasing doses. At first sight this phenomenon would seem to point to the establishment of tolerance, but since it is found that the dose can, in the course of about three weeks, be increased to five hundred times the original amount, tolerance can no longer be accepted as an explanation, as we know of nothing analogous to such a rapid and complete adaptation to an extremely active remedy. The phenomenon must rather be explained in this way—that in the beginning of the treatment there is a good deal of tuberculous living tissue, and that consequently a small amount of the active principle suffices to cause a strong reaction; but by each injection a certain amount of the tissue capable of reaction disappears, and then comparatively larger doses are necessary to produce the same amount of reaction as before. Within certain limits a certain degree of habituation may be perceived.

As soon as the tuberculous patient has been treated with increasing doses for so long that the point is reached when his reaction is as feeble as that of a non-tuberculous patient, then it may be assumed that all tuberculous tissue is destroyed. And then the treatment will only have to be continued by slowly increasing doses and with interruptions, in order that the patient may be protected from fresh infection while bacilli are still present in the organism.

Whether this conception, and the inferences that follow from it, be correct, the future must show. They were conclusive as far as I am concerned in determining the mode of treatment by the remedy, which, in our investigations took the following form.

THE TREATMENT APPLIED TO LUPUS.

To begin with the simplest case, lupus. In nearly every one of these cases I injected the full dose of 0·01 cubic centimeter from the first. I then allowed the reaction to come to an end entirely, and then, after a week or two, again injected 0·01 cubic centimeter, continuing in the same way until the reaction became weaker and weaker, and then ceased. In two cases of facial lupus the lupus spots were thus brought to complete cicatrization by three or four injections. The other lupus cases improved in proportion to the duration of treatment. All these patients had been sufferers for many years, having been previously treated unsuccessfully by various therapeutic methods.

THE TREATMENT APPLIED TO TUBERCULOSIS OF THE BONES AND JOINTS.

Glandular, bone, and joint tuberculosis were similarly treated, large doses at long intervals being made use of. The result was the same as in the lupus cases—a speedy cure in recent and slight cases, slow improvement in severe cases.

THE TREATMENT APPLIED TO PHTHISIS.

Circumstances were somewhat different in phthisical patients, who constituted the largest number of our patients.

Patients with decided pulmonary tuberculosis are much more sensitive to the remedy than those with surgical tuberculous affections. We were obliged to lower the dose for the phthisical patients, and found that they almost all reacted strongly to 0·002 cubic centimeter and even to 0·001 cubic centimeter. From this first small dose it became possible to rise more or less quickly to the same amount as is well borne by other patients.

Our course was generally as follows:

An injection of 0·001 cubic centimeter was first given to the phthisical patient. On this a rise of temperature followed, the same dose being repeated once a day, until no reaction could be observed. We then rose to 0·02 cubic centimeter, until this was borne without reaction, and so on, rising by 0·001, or at most 0·002, to 0·01 cubic centimeter and more. This mild course seemed to me imperative in cases where there was great debility. By this mode of treatment the patient can be brought to bear large doses of the remedy with scarcely a rise of temperature. The patients of greater strength were treated from the first, partly with larger doses, partly with rapidly repeated doses.

Here it seemed that the beneficial results were more quickly obtained.

The action of the remedy in cases of phthisis generally showed itself as follows:

Cough and expectoration generally increased a little after the first injection, then grew less and less, and in the most favorable cases entirely disappeared. The expectoration also lost its purulent character, and became mucous.

As a rule the number of bacilli only decreased when the expectoration began to present a mucous appearance. They then from time to time disappeared entirely, but were again observed occasionally until expectoration ceased completely. Simultaneously the night sweats ceased, the patients' appearance improved, and they increased in weight. Within four to six weeks patients under treatment for the first stage of phthisis were all free from every symptom of disease and might be pronounced cured. Patients with cavities not yet too highly developed improved considerably, and were almost cured. Only in those whose lungs contained many large cavities could no improvement be proved objectively, though even in these cases the expectoration decreased, and the subjective condition improved. These experiences lead me to suppose that phthisis in the beginning can be cured with certainty by this remedy.*

EFFECT IN ADVANCED CASES OF PHTHISIS.

In part this may be assumed for other cases when not too far advanced; but patients with large cavities, who almost all suffer from complications caused, for instance, by the incursion of other pus-forming micro-organisms into the cavities, or by incurable pathological changes in other organs, will probably only obtain lasting benefit from the remedy in exceptional cases. Even such patients, however, were benefited for a time. This seems to prove that, in their cases, too, the original tuberculous disease is influenced by the remedy in the same manner as in the other cases, but that we are unable to remove the necrotic masses of tissue with the secondary suppuration processes.

The thought suggests itself involuntarily that relief might possibly be brought to many of these severely afflicted patients by a combination of this new therapeutic method with surgical operations (such as the operation for empyema), or with other curative methods. And here I would earnestly warn people against a conventional and indiscriminate application of the remedy in all cases of tuberculosis. The treatment will probably be quite simple in cases where the beginning of phthisis and simple surgical cases are concerned; but in all other forms of tuberculosis medical art must have full sway by careful individualization, and making use of all other auxiliary methods to assist the action of the remedy. In many cases I had the decided impression that the careful nursing bestowed on the patient had a considerable influence on the result of the treatment, and I am in favor of applying the remedy in proper sanatoria as opposed to treatment at home, and in the out-patient room. How far the methods of treatment already recognized as curative—such as mountain climate, fresh air treatment, special diet, etc.—may be profitably combined with the new treatment cannot yet be definitely stated, but I believe that these therapeutic methods will also be highly advantageous when combined with the new treatment in many cases, especially in the convalescent stage.† The most important point to be observed in the new treatment is its early application. The proper subjects for treatment are patients in the initial stage of phthisis, for in them the curative action can be most fully shown, and for this reason, too, it cannot be too seriously pointed out that practitioners must in future be more than ever alive to the importance of diagnosing phthisis in as early a stage as possible. Up to the present the proof of tubercle bacilli in the sputum was considered more as an interesting point of secondary importance, which, though it may render diagnosis more certain, could not help the patient in any way, and which, in consequence, was often neglected. This I have lately repeatedly had occasion to observe in numerous cases of phthisis which had generally gone through the hands of several doctors without any examination of the sputum having been made. In future this must be changed. A doctor who shall neglect to diagnose phthisis in its earlier stage by all methods at his command, especially by examining the sputum, will be guilty of the most serious neglect of his patient, whose life may depend on this diagnosis, and the specific treatment at once applied in consequence thereof. In doubtful cases medical practitioners must make sure of the presence or absence of tuberculosis, and then only the new therapeutic method will become a blessing to suffering humanity, when all cases of tuberculosis are treated in their earliest stage, and we no longer meet with neglected serious cases forming an inextinguishable source of fresh infections. Finally, I would remark that I have purposely omitted statistical accounts and descriptions of individual cases, because the medical men who furnished us with patients for our investigations have themselves decided to publish the description of their cases, and I wish my account to be as objective as possible, leaving to them all that is purely personal.

* This sentence requires limitation in so far as at present no conclusive experiences can possibly be brought forward to prove whether the cure is lasting. Relapses naturally may occur, but it can be assumed that they may be cured as easily and quickly as the first attack. On the other hand, it seems possible that, as in other infectious diseases, patients once cured may retain their immunity. This, too, must, for the present, remain an open question.

† As regards tuberculosis of brain, larynx, and miliary tuberculosis, we had too little material at our disposal to gain proper experience.

A COMFORTABLE HEN HOUSE.

AT this season, in our climate, the matter of having a comfortable place in which to winter poultry is an all-important problem. I, therefore, present a sketch of my winter quarters for fowls.

In building, my main ideas were warmth and security, as in this section thieves are often successful in their raids. As economy was imperative, rough pine lumber was used throughout, no attention being paid to appearances, except in the matter of making a generally neat-looking job. As I had in the neighborhood of only twenty hens to winter, I concluded that a roosting place twelve feet long and six feet wide would be large enough, that being the size of the rear building in the illustration, the highest northern side being seven feet and the other four feet in height, thus giving sufficient pitch to the roof and at the same time being large enough to admit of all the necessary work being done without discomfort.

In this roosting house particular attention was given as to warmth. Of course, with a number of chickens together, the animal heat is considerable, but this is quickly overcome if the house is not pretty tight and free from drafts. My fowls are single-combed white Leghorns, and while they are among the hardiest of the smaller breeds, yet their magnificent combs are a tender spot, so I took some extra precautions. The floor framework was laid on posts, a foot above the ground surface, and although a single thickness of inch boards for the floor was used, yet, as it will be perfectly dry and the outside will be warmly banked up, I think that it will do first rate, especially as I keep a layer of dry ashes, earth or sand on the floor under the roosts all the time.

The sides and ends are double boarded, with a two and a half inch air space between the boards forming the inside walls, are laid horizontally in the longest direction, in order to make as few cracks and joints as possible, so that lice, if by chance they got a foothold, would find but little lodging room. Immediately on these boards, on the outer side, was tacked some thick, fresh-smelling tar paper, the edges of which were lapped enough to render it impervious to all air currents, the ends being left long enough to close the cracks where the roof boards lay on the top of the sides.

The boards on the outside were put on perpendicularly, running from the roof to the ground, the cracks being closed with battens. For the roof, inch boards were laid on tightly together, covered with the tar paper and then shingled with medium quality shingles. In one end a window was placed, two sash exactly alike were used and placed in double, just as the boards were, all of the joints and cracks being made tight with tar paper. The door was also made double with tar paper between the two thicknesses of boards. The door frame and the door were so fitted that there was a lap joint of two inches all around when the door was closed.

When completed, the building would have been nearly air-tight had it not been for the ventilator, which was against the back wall in the center of the house. The portion of the ventilator which is seen above the roof in the illustration has a partition in the

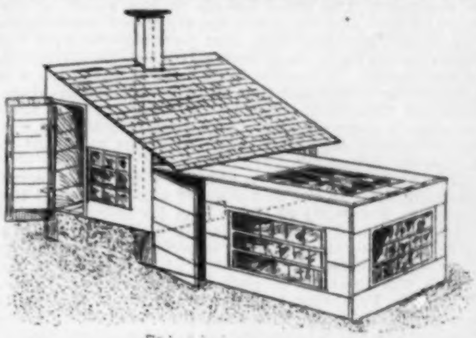


FIG. 1.—A COMFORTABLE HEN HOUSE.

center, as shown by the dotted line. The portion to the right of the partition goes down into the house only about four inches below the roof, thus being in the highest part of the house, and affording an egress for the impure air, which, being heated by the fowls, rises to the top and out through the ventilator. The portion to the left of the dividing line in the ventilator goes down to within four inches of the floor, and supplies pure air in place of that which passes off. As the cold air from the outside is the heavier, it first spreads along the floor, gradually rising, until by the time it reaches the birds on the perches, two feet above the floor, it has become somewhat warmed. As the ventilator is not large, each compartment being only an inch and a half square, the air cannot change rapidly enough to rob the house of any great portion of the heat generated by the fowls. Even on the coldest nights the temperature will not fall below freezing.

Before the chickens were allowed in this roosting place, the inside was given a heavy coat of whitewash, into which was stirred a little carbolic acid. The perches were also well soaked with kerosene oil, and, although no lice were observable on the chickens, they were each given a good dusting with Persian insect powder.

As before mentioned, I keep a layer of coal ashes, dry earth or sand, on the floor under the perches. I prefer the ashes; each day a panful is taken from the stove and spread evenly over the floor. The following morning, before putting on the fresh ashes, I take a rake and stir up the old ones and the droppings, then throw the new ashes over the old. This is repeated until three panfuls of ashes has been used, each time stirring them and the manure well together; then the mixture is swept out of the house and stored in a bin where it will keep perfectly dry. I calculate that in this way each fowl will make at least fifty cents' worth of valuable fertilizer during the winter.

The house is thus kept perfectly clean, the time required being only about five minutes a day, except twice a week, when a quarter of an hour will be needed to clean out properly.

As the roosts do not take up much more than half the space, the rest is used as a nest room, a set of nests being shown at Fig. 2. It is simply a tight box about 15

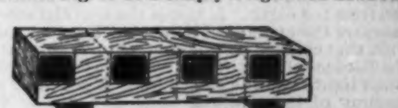


FIG. 2.—A SET OF FOUR NESTS.

in. square and 6 ft. long, divided into four compartments. On the bottom and half way up the sides of each nest is fastened a piece of tar paper, and on this a little dry straw is placed. The only openings are the holes shown in front, which keep it perfectly clean. The whole thing is placed on bricks to raise it somewhat from the floor.

The building in the foreground of Fig. 1 is a feeding place during the winter. It is 16 ft. long, 9 ft. wide and 4 ft. high, made of rough pine lumber, with the cracks closed with tar paper or else battened. As it often happens during the winter that they cannot run about much, this place is made very light by the use of four sash, one on each side, one in the end and on the roof; as this is the southern end of the building it will thus have the benefit of all the sunshine there is, and during the day, even in the severest weather, will be quite comfortable. The ground floor is raised some inches above the outside surface, which keeps it dry, and on this I keep several inches of chaff and sand.

When the chickens are fed grain in this building, as is often the case in winter, it is scattered in the chaff, and they are kept busy scratching all day in this manner, which helps to keep them warm and contented. On every fine day they are allowed to range as much as they please, in order to have them confined as little as possible. Of course this building being so low will not admit of much work being done in it, and but little is

needed, as it is only necessary to change the chaff a couple of times in the course of the winter.

Dusting boxes are kept in this pa.t also, in which several times a week warm coal ashes are placed and covered with dry earth or sand; these are greatly enjoyed. Air-slaked lime is kept in another box, as also are crushed oyster shells. Fresh water is provided every day, together with a variety of foods. Under this care our hens have done exceedingly well, have not been troubled by any disease, lice or other drawback. Gradually I expect to increase my flock and erect more commodious houses, but I believe that to commence in a small way is the only successful method of getting a fair return from chickens.—*E. R. S., Country Gentleman.*

ORION.

The splendid constellation of Orion, which is just now beginning to adorn the early morning skies, and will be a conspicuous ornament of the winter evening heavens, has lately assumed a fresh interest for astronomers and for all who delight in the contemplation of the universe. In the united splendor of its stars Orion is unrivaled; the great nebula in the sword of the celestial hero and the many beautiful and remarkable double and multiple stars that are scattered over the constellation have long been an irresistible attraction to star gazers. It has also been known that Orion was remarkable for the fact that all of its conspicuous stars, with one exception, show by their spectra that they are alike in their physical make-up and condition. It has even been suggested that they ought to be put in a class by themselves.

Now new light is thrown upon this matter by recent photographs. In the first place, it was shown that the nebula in the sword of Orion was far more extensive than it appeared to be in drawings made with the eye and telescope alone. The sensitized photographic plate was affected by rays of light from parts of the nebula too faint to be perceived by the eye. Then Prof. W. H. Pickering, from the top of Mount Wilson, in Southern California, with a small portrait lens, photographed the whole constellation and discovered that it is enveloped in an enormous spiral nebula, no less than 15° in diameter! The old nebula in the sword is simply a brighter patch in that stupendous system. All the appearances indicate that the thousands of stars sprinkled over that region are connected with the nebula; have, so to speak, been born out of it by the process of condensation. Owing their origin to the same mother nebula, they naturally exhibit a spectroscopic resemblance to one another. But the process of stellar creation is not at an end there. The nebula is still condensing; its vast streams of unformed matter, whether composed of meteors or of gases, are either pouring into the suns already formed or tending toward new centers of condensation. The rush and whirl and sweep of demiurgic powers and forces in that vast cosmic workshop bewilder the imagination. In our part of the universe chaos has long since ceased to reign, and sun and planet have fallen under the regular sway of gravitative forces reduced to their simplest and most orderly expression. Meteors, it is true, still fall upon the earth, and more abundantly upon the sun; and now and then a new comet is drawn into the solar system; but broadly speaking, surrounding space has been swept nearly clean of scattered matter. Out yonder in Orion a very different condition prevails. The fiery rain of meteoritic matter plunging toward thousands of new-formed suns, and the vast streams, currents, and whirlpools of the nebula not yet condensed into solar nuclei, fill milliards of milliards of milliards of cubic miles of space with a scene of chaos almost too grand and awful for man to imagine.

Nor are the suns already formed in Orion insignificant members of the celestial host. Quite the contrary; some of them are evidently of enormous magnitude and brilliancy, transcending even such solar giants as Sirius, Arcturus, and Vega. If all the stars apparently connected with the Orion nebula really belong to a system by themselves, then the star named Rigel, which is included in one corner of the nebula, and exceeds all the others in apparent brilliancy, must actually be the greatest member of the system. Rigel is so distant that the results of all attempts to ascertain its parallax are more or less unsatisfactory. One estimate recently made is that light requires 490 years to come to us from Rigel. Light travels about 5,860,000,000,000 miles in a year; consequently the distance of Rigel must be 2,870 millions of millions of miles, or more than 30,000,000 times the distance of the sun from the earth. If this is the true distance, we can compare the amount of light that Rigel actually emits with that emitted by our sun. At our present respective distances from the two we get 40 000,000,000 times as much light from the sun as from Rigel. But since the amount of light falling upon any surface varies inversely as the square of the distance of the source of the light, it follows that the sun if removed to 30,000,000 times its present distance would shed upon the earth only one-nine-hundred-million-millionth as much light as it now gives us. Multiplying this fraction by 40,000,000,000, which expresses the ratio of the sun's light to Rigel's at our present distance from each, we get 22,500, which is the number of times Rigel actually exceeds the sun in light-giving power.

It is difficult to imagine such a sun as that. Our planetary system removed to Rigel, with its present orbital dimensions, would not only be uninhabitable, but the innermost planets, including the earth, would melt and dissolve in the intense heat. The sun is unable to furnish to Neptune, at a distance of 2,800,000,000 miles, sufficient heat to keep it from freezing. In fact, Neptune gets only one nine-hundredth as much solar light and heat as we do. But if Neptune were a satellite of Rigel at the same orbital distance, it would be turned into a blazing world, receiving twenty-five times as much heat as the earth gets from the sun. The region of space that Rigel can render habitable by its radiation is, of course, immensely greater than that which owes a similar debt to the sun, so that if it possesses a planetary system, it must be of metropolitan proportions.

While the distance that we have deduced for Rigel is based upon hypothetical data, yet it must not be assumed that it is on that account necessarily exaggerated. As a matter of fact, the apparent displacement of the stars by the motion of the earth, upon which estimates of their distance depends, is so exceedingly minute that in only a few cases can it be measured with approximate accuracy, and this very fact may be taken to show that the estimates of stellar distances are far more likely to be too small than too large. The distance of the nearest known star in the heavens is less than one-hundredth as great as that assumed for Rigel, but it would be presumptuous to assert that there may not be among the 100,000,000 visible stars (out of which less than fifty have been found within a measurable distance from us) some that are a hundred times as much further away as Rigel is.

People who fear that our globe is going to get overcrowded may find comfort in the assurance that there is plenty of room beyond the earth.—*New York Sun.*

"WILD BEASTS AND THEIR WAYS."

The veteran sportsman, great African traveler and geographical explorer, and founder of Egyptian rule in the Equatorial Soudan, whose well earned fame has lost nothing by the disaster of Khartoum, the lamented death of General Gordon, or the achievements of Mr. H. M. Stanley, now presents us with a new book which will be read with interest by every lover of animal nature, as well as by all curious to know the most improved methods and instruments of killing dangerous and destructive beasts. Sir Samuel Baker, who published his "Rifle and Hound in Ceylon" in 1854, after eight years' residence in that island, where he and his brother established the useful plantation and sanatorium of Newera Ellia, writes of the shooting of big game, with the authority of forty-five years' experience, in Europe, Asia, Africa, and North America; and both his introductory chapter and frequent practical remarks aptly introduced throughout these two volumes are earnestly intended to enforce certain advice on the choice of rifles and ammunition.

The recent loss of valuable lives among English gentlemen risking a conflict with elephants, buffaloes, or tigers, with some fashionable weapons or bullets which have not an immediately killing effect is constantly present to his mind. His personal references to those unfortunate instances are inspired by kind and generous feeling. We observe that he three times incidentally relates the death of the late Mr. Walter Ingram in Somaliland, the circumstances of which are in the remembrance of our readers, and cites also that of the Hon. Guy Dawnay, as examples in proof of the inadequate power of a 0·450 bore rifle in a facing shot at the elephant or the buffalo; while his condemnation of the hollow bullet often used with express rifles is reiterated again and again, and is particularly illustrated by Mr. Cuthbert Fraser's perilous adventure with a tiger in India. Sir Samuel Baker insists on the use of solid bullets, weighing 650 grains, which should be of hard metallic compound for thick-skinned animals, but for lions, tigers, and large deer should be of pure lead; this latter bullet will go through the body, not breaking up into little pieces like the hollow bullet, but will expand, by pressure against the bones and sinews, to a flattened front width, about an inch and a half. It may then be stopped by the inner surface of the skin on the opposite side of the body, and so much the better, for the animal is then brought to the ground with the full force of the stroke, reckoned at 3,520 lb. to the square foot with a 0·577 bore rifle, a powder charge 6 drachms, and a solid bullet. If the bullet passes out of the body on the other side, a portion of this force is lost. But for elephants, and other large thick-skinned beasts, Sir Samuel Baker recommends a still more powerful weapon, the "Paradox. No. 12," or the "Paradox, No. 8," with a bullet of 1¾ oz., even 3 oz. for the number 8, and a charge of ten, twelve, or more drachms of powder. Only strong men could use such fire arms as these, but the author once had a rifle that carried a three ounce spherical bullet, four ounce conical, or half pound shell, with a propelling charge of sixteen drachms: "there were giants in those days." The rifle, made at Bristol in 1840, weighed 21 lb., and was his companion many years in Ceylon.

THE CIRCLE OF FIRE.

These curious and useful details of shooting apparatus are however forgotten in pursuing the business-like accounts of Sir S. Baker's experiences with the elephants and tigers of India, which are the most interesting part of the first volume. The natural history of the elephant, in Africa as well as in Ceylon and India, is described in three chapters, with the employment of the Indian elephant in tiger hunting, more completely and precisely than in any other book we have read. The African elephant is much the grander animal, rising to a stature of 11 ft. or 12. ft. at the shoulder: we are told that there is nothing in India to approach the size of Jumbo. The author thinks there is no reason why African elephants should not be tamed and trained to the service of man.

We believe there is no proof of its having ever been done. The Carthaginian army of Hannibal possessed some elephants, but they may have been imported by the Phenicians from Ceylon. The natives of Africa nowhere care for capturing and domesticating wild animals. If the British East Africa Company would try the experiment, aided by such an able manager as Mr. G. B. Sanderson, the renowned official superintendent of the Government "Keddhas" at Dacca and in Assam, we should soon learn whether the finest race of elephants on earth can be rendered useful. At present, though valuable for ivory, the pair of male tusks averaging 140 lb. weight—some specimens being

A CHALLENGE TO THE LINE OF ELEPHANTS.

300 lb. and being borne by both sexes in Africa—the living animals are an unmitigated nuisance, destroying the crops of grain and causing misery to the native population.

The ivory trade itself is the main support of the Arab slave-raiding cruelties, as the people are kidnapped, not primarily for sale as slaves, but for the purpose of carrying ivory to the coast. If the African elephant were utterly exterminated, it would be a greater boon to African mankind, we doubt not, than would be the extermination of tigers and leopards in India to our Asiatic fellow subjects. Carnivorous beasts of prey, which kill cattle, and occasionally kill human beings, may really be less mischievous than herds of such wastful monsters as elephants among the native agriculturists of Africa. It is satisfactory to be told of many native contrivances for destroying elephants. Pitfalls, dug 12 ft. or 14 ft. deep, covered with a frail roof of branches, grass, and earth, catch many, which are then speared to death.

"There is another terrible method of destroying elephants in Central Africa. During the dry season, when the withered herbage, from 10 ft. to 14 ft. in height, is most inflammable, a large herd of elephants may be found in the middle of such high grass by some native hunter, who would immediately give notice, and the whole population of the neighborhood would assemble for the hunt. This would be arranged by forming a circle of perhaps two miles diameter, and simultaneously firing the grass, so as to create a ring of flames round the center. An elephant is naturally afraid of fire, and has an instinctive horror of the crackling of flames when the grass has been ignited. As the circle of fire contracts in approaching the encircled herd, they at first attempt to retreat, until they become assured of their hopeless position; they at length become desperate, being maddened by fear, and panic stricken by the wild shouts of the thousands who have surrounded them. At length, half suffocated by the dense smoke, and terrified by the close approach of the roaring flames, the unfortunate animals charge recklessly through the fire, burnt and blinded, to be ruthlessly speared by the bloodthirsty crowd awaiting this last stampede. Sometimes a hundred or more elephants are simultaneously destroyed in this wholesale slaughter. The flesh of every portion of the animal is then cut into long strips, dried and smoked on frames of green wood, and the meat is divided among the villages which have contributed to the hunt. The tusks are also shared, a certain portion belonging by right to the various headmen and the chief." We are permitted by the publishers, Messrs. Macmillan & Co., to produce in our own pages four of the engravings which adorn Sir Samuel Baker's two volumes; one is that of the "Circle of Fire."

The natives in another district, which he does not name, kill elephants in the forest by waiting for them in the branches of large trees overhead, and being furnished with enormous daggers, or rather axes, 2 ft. long, several inches wide, very sharp at the point and both edges, and heavily weighed at the top with clay, drop these terrible weapons from a considerable height, piercing the elephant's back just behind the shoulder. The Hamran Arabs of the Settite River, described in Sir S. Baker's book "The Nile Tributaries of Abyssinia," are brave horsemen and swordsmen, who carry a long two-handed sword; three of them hunt an elephant; one provokes the animal and gallops away, pursued by the infuriated beast, two or three hundred yards, at a speed of eighteen or twenty miles an hour; then he stops, and, just as the elephant is preparing to charge, the other men, riding up and dismounting, cut the back sinew of the elephant's hind legs with one stroke of their swords. The huge beast is quite crippled and soon bleeds to death.

The elephant in India, though naturally timid and less intelligent than has been imagined, plays a most important part as man's ally in hunting the tiger. In the narratives of Sir Samuel Baker's experiences of this kind, with Mr. Sanderson, in 1885, in the grassy islands of the Brahmaputra, below Dhubri, and in the Central Provinces, near Moorwarra, with the late Mr. Berry, Assistant Commissioner of Jubbulpore, we find many characteristic anecdotes of the behavior of elephants in situations of danger. They are very apt to take fright, throw themselves about, turn tail and run away; then in the forest their riders are in great risk of being knocked out of the howdah, or having their heads and limbs broken against the branches of trees. But a long line of elephants, from twelve up to thirty or forty, is required to beat the covert of tall grass, tamarisk trees, wild briar rose, or other jungle, which may be a task of several hours. The tiger in such places will not be seen till within fifty yards, or nearer, and Sir S. Baker has found a smooth bore gun, at such short range, quite as useful as a rifle. He sometimes fired it with one hand, like a pistol, while holding on to the howdah rail with his left hand, shooting rapidly as at flying game without squinting along the sights on the barrel. The second illustration we have borrowed is that of a line of Mr. Sanderson's elephants, from the Garo Hills, being deliberately challenged by a large tiger, which bounded along their front, making demonstrations of attacking each elephant in succession, but which Mr. Sanderson shot and killed. It was sent to Lady Baker, at the camp; that lady had, on a preceding day, been with her husband on an elephant, when he "wiped the eye" of the Rajah Suchi Khan by killing a tiger which the Rajah had only wounded.

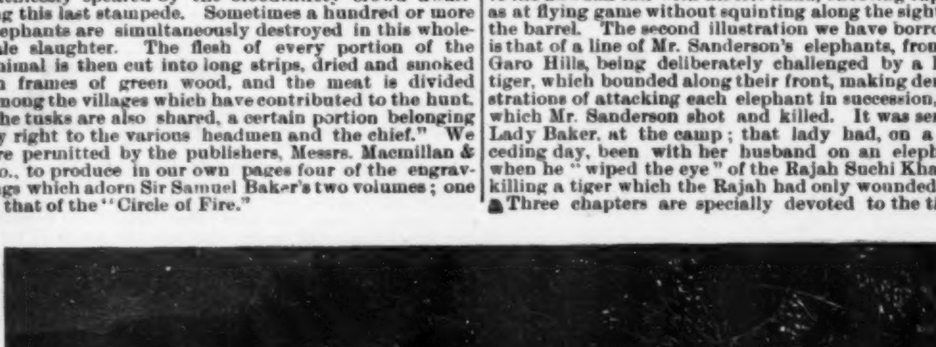
Three chapters are specially devoted to the tiger; one only to the lion, which is now getting very scarce in Asia, being confined, we learn, to a limited number in Guzerat (India) and a few in Persia. We have never been able to regard the lion as a finer animal than the tiger. Apart from the imposing aspect of his face and shaggy mane, his shape is not so handsome; and the superiority of his strength lies in the stroke of the fore paws, and also in the jaws, not equally in his whole body. Sir Samuel Baker gives him credit for a sort of frank courage, differing from "the slinking habits of tigers, leopards, and the feline race generally;" which may be only the comparative stupidity of the lion.

Many other African travelers and hunters entertain no great respect for this powerful beast. It is true that a blow of the lion's paw will smash a man's skull or spine, while the tiger's claw only lacerates the head and face; the tiger kills by biting over the man's shoulder through his back and chest. But a single lion is hardly a match for the buffalo; two or three lions will attack together. Nevertheless, as the so-called "King of Beasts" is so famous in poetic and romantic allusions, we choose, for the next of our borrowed illustrations, that of a big lion, on the Settite River, prowling at night around the fenced camp, to which Sir S. Baker, with a Hamran Arab and three Tokrooris, had retired. The lioness had been shot and brought into this camp the day before; and this faithful leonine husband came to ask what they had done with his wife, but found "no admittance" through a strong fence of tree stems and kittur thorns: next day, the lion also was shot.

Other wild beasts, the leopard and hunting cheetah, the North American and the Indian bear, the hippopotamus and rhinoceros of Africa, the crocodile (not a beast), the buffalo and bison, the boar, the hyena, the giraffe, antelopes, deer, sambur, wapiti, and cervine varieties, are discussed in these instructive volumes. We conclude an imperfect review with brief notice of the native method of snaring the rhinoceros in the region east of the White Nile. The beast comes regularly every night to one spot, to deposit its dung against the stem of a certain large tree. A trap for one leg is constructed, a small round hole covered with a neatly made sieve of wood and bamboo which sticks to the leg when thrust into the hole. A noose of rope is laid around it, to which is attached a heavy log of timber slightly buried in the earth. The animal gets his leg entangled by this noose, and runs off with the encumbering log, which soon catches in the bushes or trees. Hunters follow, and kill the rhinoceros with their spears, as is shown in the engraving.

The flesh of this animal is eaten by the Soudan Arabs, but is refused by the savage tribes; its hide and horns fetch a good price. In Africa, evidently, the wild men have their own ways of dealing with the wild beasts; yet the civilized sportsman, owning a 0·577 rifle, with cartridges of 6 dr. powder and solid bullets of 650 gr., can do a great deal of good. He can often by one day's skillful work supply food to a populous village, and rid the dhurra fields of a destructive pest. The English hunter of big game is a benefactor to African humanity, but his pastime will be over, we expect, in less than a quarter of a century hence.—*Illustrated London News.*

FOLLOWING THE NOOSED RHINOCEROS.



THE LION.

THE MANUFACTURE OF HYDROGEN DIOXIDE.

By A. BOURGOUGNON.

IN 1878, I manufactured hydrogen dioxide on a commercial scale, and the following is a description of the method I adopted for the preparation of this bleaching compound:

The first step, and a very important one, is the hydration of the barium dioxide. Into a suitable vessel—an ordinary cylindrical stone pot, about half full of water—the powdered dioxide is slowly poured, the mixture being well stirred with a wooden spatula during this operation, and continued after its completion for about twenty minutes. Then the mixture is left alone, and stirred every half hour or oftener for about ten minutes, until the hydration is completed. This operation requires from three to four hours; the barium dioxide forms then a thick, perfectly white and smooth, pasty mass, resembling white clay mixed with water.

While the hydration is progressing, a mixture of water and hydrofluoric acid is made in a vessel lined with sheet lead, and surrounded with ice, or simply with water in which lumps of ice are placed from time to time, so as not to allow the temperature of the acid mixture to rise above 10° C. during the operation.

All things being properly disposed, the hydrated barium dioxide is added in portions of three to four pounds at a time to the acid mixture, stirring all the time to mix the contents of the vessel thoroughly. All the barium is transferred to the acidulated water in about two hours, and the agitation continued for four hours. If the operation has been well conducted, all the barium dioxide is transformed into fluoride, which falls to the bottom of the vessel. When this precipitate is well settled, the supernatant liquid is decanted into a vessel similar to the one used for its production, and also surrounded by ice water. The clear liquid contains an excess of acid and impurities derived from the materials employed; its color is yellowish, and it must be purified to insure its keeping properties.

The impurities which are to be removed are chiefly ferric oxide, alumina, and manganese oxide. To the cold solution of impure hydrogen dioxide small quantities of hydrated barium dioxide are added at a time and well stirred. When the last traces of acid are saturated, the appearance of the liquid suddenly changes, from a bright yellow it turns to a grayish color, and the impurities are separated and collected at the surface of the liquid.

Without losing time, the liquid is filtered through a cheese cloth stretched on a frame, and received in a vessel which contains a small quantity of sulphuric acid diluted with eight to ten times its volume of water (acid, 1 oz.; water, 8 to 10 oz.). This filtration must be quickly done. As long as the solution is alkaline, there is great danger of decomposition and loss of oxygen. If the liquid is thrown upon the filter, the latter will be quickly clogged, the filtration stopped, and the hydrogen dioxide will rapidly decompose, emitting large bubbles of oxygen with a hissing noise; but as the precipitated impurities collect first on the top of the

liquid, if the solution is siphoned from below these impurities, the liquid filters quickly and satisfactorily.

The filtered liquid is tested for barium, and sulphuric acid is added to it until all is removed. The liquid is left overnight, the precipitate of barium sulphate settles, and the perfectly clear and colorless liquid is ready for the market.

All the precipitates are separated by pressure from the liquid they may contain, and the liquid so obtained is added to the water employed in the next operation.

I employed the following proportions:

Barium dioxide	60 lb.
Hydrofluoric acid	25 "
Water	40 gallons

and obtained nearly 40 gallons of hydrogen dioxide. The strength of the acid was about 33 per cent.—*Journal of the American Chemical Society.*

A NEW CECIDOMYIID INFESTING BOX-ELDER

(*Negundo Aceroides*).*

By C. P. GILLETTE, Ames, Iowa.

CECIDOMYIA NEGUNDINIS n. sp.

Galls.—The galls (G) are produced from terminal buds on all parts of the tree. Each is made up of a number of transformed leaves and petioles arranged in pairs in which the two leaves are opposite. They are subglobular in outline, and vary from less than one half an inch to nearly an inch in diameter. The outer basal portion of the gall is formed by an enormous enlargement of the bases of the petioles of two leaves which unite and form a receptacle like the cup of an acorn holding the inner portions of the gall. In the central part of the gall, the leaf blades may be entirely involved or their tips may be partially expanded.

Gall Flies.—Females, dry specimens. *Eyes* large, coal black, and coarsely granulated; *antennæ* one-half the length of the insect, 13-jointed, first joint globular, remaining joints cylindrical, second and third joints contracted in the middle, pedicels of joints short, about one-quarter the length of the joints, all of the joints moderately set with hairs, the longest of which nearly

CECIDOMYIA NEGUNDINIS n. sp.

Adult female: O, ovipositor; E, eggs; G, Gall. Fly and eggs greatly enlarged, gall slightly enlarged. Original.

equals the joints in length. *Thorax* very dark brown, opaque, and naked except two rows of long gray hairs in longitudinal grooves running from collar to scutellum and similar hairs at the sides of the thorax; scutellum of the same color as the mesothorax, and with a few long gray hairs. Beneath the wings it is yellowish. *Dorsum* dark brown, sides of *abdomen* and venter light yellow; abdomen sparsely set with gray hairs above and below. *Ovipositor* yellowish brown, and in specimens taken while ovipositing, it is exserted one and one-half times the length of the insect. *Legs* rather pale, tibiæ and tarsi infuscate, rather densely set with silvery hairs. *Wings* beautifully iridescent and rather sparsely set with long gray pubescence, fringed all the way around; costal and first longitudinal nervures rather heavy and united at the apex of the wing as one continuous vein. The little cross vein between the first and second transverse nervures and the outer or upper branch of the fork in the third transverse nervure are almost obsolete and scarcely visible except in favorable light. Length of dry specimens one and one-half mm. Length of fresh specimens two mm.

The eggs (E) are a bright orange color, 0·4 mm. in length, and much elongate. Some are straight, others are variously bent, and all are pointed at one end, and often with a short pedicel attached.

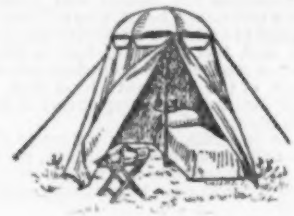
This insect is decidedly an injurious species. Trees upon the college campus that were the most severely attacked by this fly the past summer have had not more than half of their normal amount of foliage this year.

On the 18th of April last, the writer noticed the flies abundant among the branches of the trees and the process of egg-laying was carefully watched with a hand lens. The females were so intent in their duties for the propagation of the species that they were not easily disturbed. They do not pierce the bud scales, but work their long, slender ovipositors far down between the scales and there deposit a large nest of eggs, sometimes forty or more in a place. By separating the scales the clusters of eggs can be plainly seen with the naked eye. The irritation set up by these eggs and the maggots that hatch from them, aided, perhaps, by a poisonous secretion from the mother insect, causes the abnormal development of the part. The galls all die a few weeks later, when the maggots leave them. These dead galls turn black and remain upon the trees, giving them an unsightly appearance.—*Psyche.*

* Read before the Iowa Academy of Science, September 5, 1890.

NEW MILITARY TENT.

THE umbrella tent is one of new design for military purposes. The method of construction of this tent admits of opening either one section or as many sections as may be desired. It can also be entirely closed by hooking up the tent flaps and closing the entrance in case of a storm, or when being used for bathing purposes.



In warm weather the walls of the tent should be staked two or three inches from the ground, which, in connection with the large opening between the umbrella and side walls, will cause a constant draught of air. The especial feature of the tent is its simple construction and portability. It folds up, and the bundle, including poles, stakes, guy lines, etc., when the tent is made of ten ounce duck, weighs about forty-six pounds. The tent was first used by the New Jersey troops at the last encampment at Sea Girt.—*Providence Journal.*

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